Journal by Alexander Graham Bell, from June 7, 1902, to December 11, 1902

TABLES IN DICTATED NOTES VOL. IV. FLYING WEIGHTS ESTIMATES BY HARGRAVE, CHANUTE & A.G.B. 769

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1902 JUNE 7. Saturday. At Beinn Bhreagh.

Relating curve & gravity, curve & surface, and point of attachment.

I have now more than one hundred small k ites, of triangular cross section well fitted for being attached to one another so as to form a compound structure of gigantic size. During the past month I have been studying the best way of combining the component parts. The importance of ascertaining the relative positions of the centre of gravity, the centre of wind pressure and the point of attachement of the flying-cords as been powerfully impressed upon me.

In fact a kite now presents itself to me as composed of three points rigidly connected together

1. The centre of Surface, which I symbolize (c). (This is a fixed point). [What we really want to knowis the centre of pressure, but as this varies with the inclination of the kite, it is difficult to ascertain it in any given case. It must however bear a certain ratio to the other three points,; Centre of surface Centre of gravity and point of string attachement — and indeed be determined by them. Hence I consider it only necessary to note the three points mentioned above.]

2. Centre of Gravity, whic I symbolize (.) This is a fixed point easily determined.

3. Point of String attachement, which I symbolize (#)

In order to determine the relative value of these three elements combined in a kite my idea has been to keep two of the elements constant, and vary the third.

?. In order to ascetain the effect of varying the centre

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1. In order to ascertain the effect of varying the centre of Surface, make a series of experiments with a kite in all of which the Centre of Gravity and Point of String Attachement occupy the same places. When you shift your eeroplanes in order to change the centre of surface the centre of gravity is also changed. It will therefore be necessary to provide a moveable weight which, at every change of aeroplane, can be shifted so as to restore the centre of gravity to its original position.

2. In order to test the effect of changing the centre of gravity, make a series of experiments in all of which the centre of surface and point of string attachement remain the same. This can be effectedby a moveable weight, which can be shifted to different parts of the kite as desired.

3. In order to test the effect of varying the point of attachement of the string, keep the aeroplane surfaces and the centre of gravity unchanged in position, and attach the cord successively at different points.

I have already made some experiments relating to these points, which show the importance of investigating them thoroughly. and systematically. Of especial importance does it seem to me to investigate the relation of the centre of gravity to the centre of surface. The experiments so far indicate that the centre of g?avity should not be in advance of the centre of surface, but a little behind it. Commencing with the centre of gravity very far back the kite flies at a low 691 angle to the horizon, with its stern very much depressed, conveying the impression of a kite too heavy to be borne by the wind;

but — without any change of win , — we find that as the centre of gravity is brought more and more forward the kite flies at a higher angle to the horizon, with its stern less and less depressed until when the centre of gravity is about under the centre of surface the highest point of flight is attained, and the body of the kite is almost horizontal. The moment the centre of geavity is in front of the centre of surface the angle of flight is reduced and the kite has a tendency to dive when gusts of wind occur. I could not test the effect of moving the centre of gravity very far forward because in such cases the kite would not fly at all.

In a kite in which the centre of gravity is directly under the centre of surface or a little behind it we may note that when the cord is attached to a point very far in advance of the centre of surface the kite flies at a very small angle with the horizon, with its body almost horizontal. As the string is attached to points successively nearer and nearer to the centre of surface, the kite flies at an higher and higher angle to the horizon, until as the points of attachement approach closely to the centre of surface an unstable coalition of flight is developed, the kite having a tendency 692 to fly off the wind, to one side and another alternately, swaying from side to side like a huge pendulum, with the hand as fulcrum and the kite as the bob, occ sc islating through an arc of many degrees. When the string is attached directly under the centre of surface flight seems to be impracticable. At least we cannot start a kite flying in that way because it presents its side to the wind instead of its end. A light kite attached in this way, and flown from the top of a pole under the action of a powerful breeze sets itself at right angles to the string, and flies with the string somewhat under the horizontal. But this is not a stable condition. A sudden gust of wind may cause it to make a sudden dart to one side or the other, or up or down, its motion being apparently unlimited within a hemisphere having the top of the pole as its centre. We could not start a kite from the ground in this way because it would be liable to make a sudden dive and dash itself to pieces with great force.

If we could get a kite up any where near the zenith by a cord attached in front of the centre of surface perhaps by shifting to another cord directly under the centre of surface the kite might fly at the zenith, or near it. I propose trying this experiment. I will have 693 three or four strings attached to a kite at different points, the first at the bow, the second a little further back, the third still further back, and the fourth directly under the centre of surface.

We will commence by the bow line Number One, leaving the other three cords slack. The kite will rise to at certaindistance in theair so that the cord will make a certain small angle with the horizon. When this point has been reached we cannot increase the angle, however much we let out the cord. But if now we slide slacken the bow line, and allow the kite to fly by cord Number Two, it will fly at a higher angle tha? than before. Then slacken cord Number Two, and allow it to fly by cord Number Three, and the flying angle will be still further increared Finally when the kite has reached its highest altitude under cord Number Three, tighten up cord Number Four (directly under the centre of surface) and note the results. Be prepared for a smash, but it may be that the wind tending constantly to liftthe kite may keep it at the zenith, or near it, the string preventing it from rising higher, and the wind preventing it from sinking lower. This may turn out to be a stable position.

A.G.B. per M.G.B.

agb

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1902, June 12 Thursday At Beinn Bhreagh Lab. Flying Kites by Multiple cords.

Some days ago we tried the experiment of flying a kite successively by cords further and further back, as noted on p. 693, and it seemed to work perfectly well. There was not very much wind at the time, so I was afraid to go as far back as the center of surface.

Starting with the bow line, we allowed the kite to rise as high as it would; then we shifted to line No. 2, and the kite rose still higher; then we shifted to cord No. 3 and it rose higher still.

It is certainly the case that the kite rose to position No. 3 with very much less strain upon the body of the kite than if we had attempted to start it from the ground by cord No. 3 alone.

In such a case the body of the kite would have been nearly vertical to the wind at starting, and the strain upon 695 the body would have been immense. With a strong breeze it would probably have eased itself by rising as shown by the arrow head. It is certainly the case that on the occasion when we made the experiment the wind was not sufficient to have lifted it from that position, if we had started it with line No. 3, and the experiment was satisfactory to my mind as to the advisability of raising a kite by successive lines attached further and further back.

We attempted subsequently to repeat the experiment in a good wind. On this occasion we had rather too much wind quite a gale was blowing from the South, or SSW. We started with the bow line, and the kite rose well, but moved uneasily about in the air. We shifted to line No. 2, and the kite rose still higher, and became more unsteady, moving from side to side like an imprisoned bear — occasionally showing a tendency to dive to one side off the wind — so that we had to slacken the cord to save the kite.

We then tried the experiment of side lines at the point No. 2, to prevent the kite from flying to one side

When flown by the two side lines the kite was perfectly steady in the air in spite of the strong wind. Gusts would occasionally send it up, but it was perfectly steady in the 696 air, and we found that we could control the movements of the kite so perfectly that we could raise it from the ground into the air, and bring it down little by little — gently — to the ground WITHOUT GOING NEAR THE KITE — a most important matter in handling a large kite, where sudden movements under gusts of wind would be apt to knock a man down or injure him should the kite strike him.

Mr. Ferguson held the bow line tight while the kite lay on the ground, and George McCurdy and I manipulated the side lines. Starting with the kite on the ground George and I walked forward parallel to one another, as shown by the arrow head

This caused the kite to glide forward on the grass against the wind, gradually arising as it moved, it then flew beautifully

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We found it was not necessary to walk forwards, as the same effect was produced by reeling in the two side lines, while we stood still.

We then allowed the kite to fly with all three strings tight, and tested the effect of varying the angle of the side lines by George and myself walking backwards and forwards on parallel paths, keeping our lines tight.

As the side lines approached more nearly to a right angle with the body of the kite, so as to come in one straight line with one another, the kite descended inch by inch as we advanced, until when we passed the right angle so as to pull a little backwards, it rested on the ground

It was really beautiful to note how perfectly the elevation of the kite was controlled by the guy lines. By walking backwards nearly to the right angle, the kite came down until 698 it was flying — and flying steadily — at about one foot from the ground. Then, by retracing our steps, it rose — little by little — higher and higher — as the angle between the guy lines became less. In all these cases the bow line also being tightened

Lowest position

Highest position

By slackening up the bow line, it rose still higher.

We consider this the most important point yet reached, as bearing upon the handling of large kites. Of course in such a case it would not be safe to handle the lines by hand, but we could handle them from tie places fastened in the ground by means of ropes, as a steamer is handled in approaching a wharf

Feeling the absolute necessity of a clear understanding of the relation of the centers of surface, gravity and string pull, I am now having made some light cells for experimental purposes, to be flown from the top of a pole. For this purpose I have adopted the hexagonal form of cell, because we 699 know where the center of surface is located. From the symetrical arrangement of aeroplanes it is obvious that the center of surface is in the geometric center of the hexagon. In this center we have placed a light aluminum pipe, through which a wooden rod can be thrust. This wooden rod protruding equally on both sides we know that the center of gravity coincides with the center of surface, and by means of a sliding weight we can shift the center of gravity forwards or backwards as desired, so that in this case the center of surface, the center of gravity, and the point of string attachment will be in one straight line — the axial line.

Then, by attaching the rod to one edge of the hexagon we can bring the center of gravity, and the point of attachment below the center of surface.

The elevation of the center of gravity is undoubtedly important, and this wants to be carefully investigate d . I am inclined to think that the center of gravity should nearly coincide with the center of surface, but that an advantage results from having the point of attachment of the string 700 below the center of surface and in front of it, because the horizontal component of string tention will then tend to tip the aeroplanes up in front, so as to catch the wind. If the center of gravity coincides with the center of surface, gravity would not tend to tip the kite one way or the other — gravity having no leverage upon it. The further off the center of gravity is from the center of surface the more would there be a tendency, I think, to a pendulum action, so that the kite would be unsteady. Of course the vertical component of string tention acts as an additional weight attached at the point where the string is attached, so that it would be important to measure the tensional force, and the angle at which the string pulls, so as to ascertain the value of the vertical component. I am inclined to think that the vertical component of string tension represents the load that would be carried by the machine as a free flying machine, if placed at the point of string attachment — hence, the importance of ascertaining its value.

By means of a spring weighing machine we can ascertain the tensional force in the direction in which the string pulls. If then, we also ascertain the angle (2) we can construct a triangle ABC, and if the line AB represents in direction of 701 and magnitude the tensional force in the string, then AC represents the load that could be carried by the kite in addition to its own weight, if attached to the point A, and the line CB represents the engine power that would be required to overcome the drift of the machine acting as a free flying machine, in order that it should hover under the wind conditions of the experiment.

The horizontal component of wind tension (theoretically) is just equal and opposite to the horizontal drift of the kite under the action of the wind.

By using hexagonal cell we know exactly where the center of surface is. By experiment we can ascertain exactly where the center of gravity is, point of attachment of the string is known. A spring weigh t ing machine will give us its tensional force, and a photograph will enable us to measure the angle the string makes with the vertical pole. The photograph, however, should be taken at a considerable distance away, with the camera on a level with the top of the pole, and in such a position that the line of sight is at right angles to the string. This position can be ascertained by the appearance of the cell, which should be seen sideways without the radial aeroplanes shown.

Then, it will be important to use two cells, two weights and two strings to ascertain the effect of extent of surface support, extent of weighted area, and extent of tensional area. A.G.B.

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1902, June 28 Saturday At B. B. Hall Mechanical soldier observed by Largelamb

Upon turning down a street — Mr. Largelamb's attention was attracted by a crowd of boys on a school was attracted by the actions of a crowd of boys in a school playground. Other passers by also — paused to gorge through the railings at the excited through within. it looked as though a fight were in progress — and the other boys had crowded round to see. Mr. H. A. Largelamb in going down the street saw a great was attracted by a crowd of boys on a school excitement in a group of boys gathered in the play ground of a neighboring school. The excitement of the boys seemed to impart itself be to spectators in the street, who stopped and gazed through the railings at the interesting sight within. Mr. Largelamb's curiosity was aroused.

The boys formed a ring all round some object on the ground. “More room”, “More room”, was shouted aloud, and the crowd of boys expanded to ring expanded to a ring of considerable size, through the line — Mr. Largelamb could just make out without approval to be two dogs held in leash by boys straining madly to get out one another. He caught fugitive glimpses of the boys apparently struggling with the dogs to keep them apart. a circle some 25 or 30 feet in diameter, with two boys in the center, and each one seemed to have a little dog tethered by a string. What in all the world they were up to he couldn't tell. He could catch glimpses of the central boys moving from side to side. He could have glimpses occasionally of the dogs dashing at one another, and of the moving, swaying crowd of boys around.

“Good Heavens”, thought he, “do they allow dog-fights in this country, and let small boys indulge in the cruel sport!”

Go he asked one of the by-standers. —“What are those youngsters fellows doing there”! he asked of a stander bye. What are they up to!” “Where are they at?”

“Fighting”, said the man, withdrawing his pipe from his mouth.

"Dogs?"

"No, soldiers" said the men "toy soldiers fighting with one another. Each boy has a soldier of his own that he can work upon the ground, and sometimes they have regular fixed battles, thirty or forty soldiers on each side."

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In the present case there were suddently only two, but it was evidently a duel to the death, and through the gaps in the ring of boys he could see the little soldiers on horseback could be seen with lances at rest, wary, warily , circling round one another, and occasionally making a dash. Each boy soldier was attended by a boy, who seemed to control the operations movements of the model on the ground horse by means of two reins, held in his hands. But the lines were slack and never tight.

This was evidently a curious and interesting game, and Mr. Largelamb determined to have a closer look at the fighters.

The reins turned out to be rubber tubes terminating in rubberballs held in each of the two hands balls, held in each hand of the boy, and the lines connecting them with the toy soldiers were formed by fine rubber tubes, and It became obvious, as Mr. Largelamb watched the boys at their play, that the models toys were operated by impulses of compressed air, sent through the rubber tubes by squeezing the rubber balls. The soldiers & horses were mounted upon wheels, forming a tricycle. a tricycle frame with two heavier two Two large wheels in front, and a small wheel one behind.

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It was obvious that each rubber ball operated one of the front wheels. When the right hand ball was squeezed the right hand wheel began to rotate, thus causing the soldier to turn to the left. When the left hand ball was squeezed the left hand wheel began to rotate, causing the model to turn to the right; and when both bulbs were squeezed at the same time the little toy soldier moved straight ahead. He moved slowly when the bulbs were pressed gently, and gave a spurt forward when the bulbs were suddenly compressed with force.

The boys had evidently acquired great skill in the operation of their soldiers. One soldier had just presented his horse's flank to the enemy, who spurred forward at the double quick to drive home his lance and . T he boy, who operated the endangered piece was frantically squeezing his rubber balls in the effort to get his man away. At each squeeze the piece shot forward, and he finally just escaped the enemy's lance. Then there was a wild chase around the moving ring of boys, to get into position for another attack. The soldiers' attendants, especially, certainly had seemed to have plenty of exercise trotting 705 after their pieces and controlling their movements.

Mr. Largelamb found out by talking with the boys that there were vital parts about the soldiers, toys which if struck by the enemy 's lance would cause valves where a blow would cause a valve to open, and let out the compressed air. He seen saw the effect of this. When one One great effect of the gou — were to disable the enemy in this way. horse was struck on the right flank operating a trigger which released a valve, and allowed it to remain permanently open. The boy operating the wounded soldier could then produce no effect by squeezing his right hand bulb, the air simply gushed out of the valve without operating the right wheel of the mechanism. The soldier was wounded, and the boy could only operate it with the left bulb, causing his piece to move round and round.

The enemy circled round the wounded man, trying to strike the fatal blow that should end the game, and the crippled piece could only move round in a circle trying to avoid presenting his left side to the enemy's lance.

At last came the coup de grace — a blow on the left side ended the battle. The vanquished soldier was dead. His attendant not able being to operate him in any way by either rubber ball.

Mr. Largelamb found that the boys were organized into war clubs, and that it was the custom of the different schools to challenge one another to battle. In the olden days, he was told the boys used to play foot ball, with the result that numerous casualties occurred at every fight. It was generally the case that some of the boys would be slightly hurt in the rough play of the game. But, the fact that several 706 fatalities had occurred in consequence of the game, excited public attention to the advisability of either abolishing the game entirely, or so modifying it as to eliminate its dangerous features.

A scientific committee examined the details concerning the large numbers of fatalities and injuries, tabulating the results, and it was found that in every case the injury was due to what was called a rush, in which a number of boys, all running from different directions, all came in contact with one another in their struggle for the ball. This feature of the game was pronounced by the scientific commission to be eminently dangerous, and they expressed the opinion that occasional injuries would be inevitable, so long as the rush was allowed. They therefore, recommended that the rush should be abolished, and that boys should not be allowed to run full tilt into one another in the game. The rule should be established that boys should never come in contact with one another. In this way alone could all danger of serious accident be eliminated.

This verdict was delivered and the school authorities proceeded to put the recommendations into execution. It seems however, that in reaching these conclusions the boys themselves had not been consulted, and when the new rules came into operation, the juvenile interest in football speedily subsided. “The rush, and struggle and tumble ” was the life of it”, said one boy, “There is no fun at all in foot ball now”, said he. And interest in the game everywhere speedily 707 lapsed.

Now, it was just at this time that the newly invented game of toy warfare came into existence, and it appealed powerfully yo the boys imagination. If the boys themselves were to be debarred from a rough and tumble fight, there could be no objection to toy boys rushing together as much as they liked. No real damage would be done to anything except days models, and the real boys would have all the fun of the thing if they could control their models at a distance themselves.

And, so the toy soldiers appeared. The school and college authorities and the United States Government saw that the new game could be turned to great use as a means of giving boys a knowledge of the laws of war, which would be invaluable to them in adult life, and to the country they represented should real war break out, and an emergency arise for the immediate employment of untrained troops.

So, great care was exercised by school and college authorities acting under the stimulus of small sppropriations from Congress — that the rules of real warfare should be carefully followed in the mimic battles of the different schools.

Mr. Largelamb was present at the annual battle between the Harvard and Yale of this country. The football grounds had been converted into a sort of map with obstacles of various character here and there. There were mountains, and trees and toy houses, and undulating sips of some material suggestive of a river. In fact, the different varieties of country in which a battle would be fought were simulated.

Then, came the two opposing armies of automobile soldiers, operated on the one side by all the members of the 708 gradutaing class of Harvard, and on the other side the graduating class of Yale. The automobiles were of two different kinds, so as to simulate infantry and cavalry. The speed of the cavalry pieces being very much greater than the speed of those representing infantry.

Behind each piece walked, or trotted his attendant student. The Generals gave their commands, the students obeyed their leader, and the pieces advanced according to a definite plan of battle, upon the enemy. The battle that ensued was of the most interesting and instructive character, and Mr. Largelamb felt that a game like that was worthy of encouragment. Healthful exercise in the participants, with interest and aroused attention all the time; individuality stimulated in each operator, and yet, subordination to a governing mind to execute a combined movement. He felt that such a game was not only of benefit to the participants as a helpful interesting, mental and physical exercise, without danger, but as a means of creating and fostering a military spirit in the people at large, and a wide spread knowledge of the laws of war — the game was really worthy of being encouraged by the government of the United States in the interests of the whole people, for it is universally recognized that the best way to secure peace is to be prepared for war. Mimic warfare as a pastime would afford the same basis of praparation for real military education as the thoughtful well directed play of girls with their dolls affords a basis for motherhood and the care of real children.

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After witnessing the interesting uses to which these toys were placed, Mr. Largelamb's curiosity was naturally aroused to ascertain the nature of the interior, hidden mechanism through which the interesting results had been achieved, and so he purchased a toy soldier and took him to pieces. The operating mechanism was simple enough to be sure. The rubber balls, or bulbs had spiral springs inside them to keep them expanded. When the bulb was squeezed the compressed air passing through a fine rubber tube entered a flat rubber bottle, looking somewhat like a rubber hot water bag in miniature, crushed flat. In fact, the rubber bottle resembled a flat disc of rubber, with a tube leading out of one end, a thing about the shape and size of a silver dollar

Upon squeezing the bulb the flat rubber bag expanded into a lense shaped form — became indeed a double convex lense of rubber. Upon releasing the bulb the spiral spring inside caused it to expand and the lense of rubber became again a flat disc

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Upon examining the interior of the tricycle supporting the soldier and his horse, Mr. Largelamb found the interior mechanism of the most ridiculous simplicity. The flat rubber bag was simply placed between two pieces of wood, the upper one hinged upon the lower, so that, when the flat bag expanded, or attempted to expand into the lenticular form, the upper lever of wood was raised up at an angle to the other

The free end of the upper lever was attached by means of a string to the axis of one of the wheels. The string was wound round the axis like a tring round a boy's top, and when the lever was raised by the expansion of the rubber bag the string caused the rotation of the axis round which it was round, moving the wheel round in like manner

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When the rubber bag collapsed the upper lever resumed the horizontal position, and the string recoiled round the axis. Mr. Largelamb then noticed that the string was not coiled around the axis itself, but around a pipe that formed a loose sleeve on the arix, and this pipe was rotated by the string against the resistance of a coiled spring, so that the moment the string tension was released the steel spring wound the whole thing up again.

Taking the thing to pieces he found that this tube, or sleeve, carried at the end abutting on the wheel, a rigid arm, or spoke, on the end of which was a moveable paul engaging a set of teeth, carried on the inner part of the rim of the wheel

When the string was pulled the sleeve rotated, the paul at the end of the radial spoke engaged in one of the teeth on the rim of the wheel, causing the whole wheel to rotate with the sleeve. A gentle pressure of the rubber bulb in the hand would cause the paul to push the wheel round a little way; whereas, a more forcible compression of the rubber bulb would cause the paul to push the wheel continuously during one 712 or more complete rotations. In every case upon the release of string tension the coiled steel spring (difficult to be shown in the drawing for any mechanician will understand it) as it is used in all sorts of contrivances, such as the spring that brings back a window curtain after you have pulled it down, any ordinary arrangement would do) — the steel spring brings back the sleeve and spoke and paul to its original position, coiling up the spring on the sleeve as it turns, while the wheel goes on rotating by its own momentum, without being specially shoved by the paul. Thus, a succession of gentle impulses from the rubber bulb would cause the wheel to rotate slowly and gently; whereas, a succession of forcible and prolongued compressions would result in the wheel rotating rapidly and forcibly.

The right hand rubber bulb operated the right driving wheel of the apparatus. The left hand rubber bulb — by means of similar mechanism operated the left hand driving wheel; and the third wheel was simply loose and followed wherever the others led

This was the character of the driving mechanism in the toy soldier opened by Mr. Largelamb; but he found, upon examining other models that the compressed air was utilized 713 in various ways in different models, although they all operated substantially on the same principle. For example, in some cases the flat bag was replaced by a cylinder and piston operating a bent crank

In other cases the piston rod produced a step by step motion, by causing a paul to engage the teeth of a ratchet wheel

Indeed he found very great varieties in the form of internal mechanism. The game was so popular, the the inventors of the country had been at work upon it, and all sorts of movements operated by successive impulses of compressed air — some even using — or rather utilizing impulses of rarified air — to operate propelling wheels, steering levers or rudders, &c., &c., and to produce a sudden thrust of the spear at the critical moment of combat — or to produce a 714 a sudden increase of speed. The power being utilized to throw the whole machine bodily against the enemy, with or without a protruding spear. There were various modifications — like the piston moving a bent crank, which allowed the machines to go backwards, as well as forward; but the preferance seemed to be for the flat rubber bag as the source of power. The expansion of the bag under the influence ofccompressed air being utilized in various ways to produce the desired movements of the apparatus.

In one curious modification Mr. Largelamb found that the rubber bulb flat bag, and connecting tube were filled with an incompressible fluid, instead of with air, and, while this form of apparatus seemed to be liable occasionally to leaks of the contained water or oil, the power produced was very much greater than when a compressible gas like air was used as the motive power.

(It is impossible here to detail all the modifications of the apparatus observed by Mr. Largelamb — nor would it serve any specially useful purpose.

Having described one apparatus that — theoretically — should work let Mr. Zable go ahead and attempt to have it made, introducing such modifications or changes as it experienced of difficulties may suggest. The electrical operation of such an apparatus will not here be considered. I have already worked at that and models made years ago are in existence. I think the phenmatic arrangement preferable on many accounts — simplicity of construction — the exercise 715 it affords the operator — reduced cost of construction, &c.

We will therefore start with the pneumatic arrangement and take up the electrical variety. A.G.B.)

716

1902, July 28 Tuesday At B. B. 716 Universal-joint weather-cask

I have often noticed that good flying kites fly very erratically when the wind is from the Northeast. It so happens that with the wind in this direction it blows down hill at the Laboratory, right towards the gulley, in which runs the water from the spring. On a few occasions I have noticed that in these bad flying spells the wind seemed to change from N. to NE, and from NE towards E. This corresponds with the lower part of an anti-cyclone. If the NE wind had been connected with a cyclone, the variation of direction would have been just the reverse, viz: — E, NE, NNE, N, the upper part of a cyclone; whereas in the observed cases it was: NW, N, NE, E.

Cyclone

Anti-cyclone

I want to keep a watch on the NE wind, to catch one connecting with a cyclone, so that we may observe whether the kites behave differently in a cyclonic NE wind from their behavior in an anti-cyclonic wind. In a cyclonic action, the air moves spirally inward towards the low, rising aa it approaches the center. In an anti-cyclonic movement the air moves spirally outward, descending as it recedes from the center, so that theoretically winds connected with a cyclone 717 should have an upward component of motion; whereas anti-cyclonic winds should have a downward component. Cyclonic winds, therefore should support kites much better than anti-cyclonic

We generally have the idea of wind as a horizontal stream of air; but this is by no means true. The researches of Langley and others relating to the internal work ing of the wind show how extremely irregular the movements of the air are when observed at any point. Even though the resultant of these innumerable and irregular variations of direction constitutes a current, it is not necessarily horizontal; cyclonic winds should blow upward, anti-cyclonic down.

Can we not make a dipping weather vane — an instrument analagous to the dipping magnetic needle — to show the upward or downward flow of the wind. Our ordinary weather vanes are so constructed that they can only show the horizontal component of the wind's direction.

Why not have your weather vane carefully balanced, and set upon a universal joint, like the swinging lamps in a ship. Instead of a flat surface to be used as a vane, use a cone, so that the wind may have full power upon it in every direction. An ordinary wind vane consisting of a plane surface would not be materially acted upon by the wind playing upon its edge — even if free to move up or down. A cone, on the other hand would be equally acted upon all round the axis of the cone, and if such a weather cock should be carefully 718 balanced in a calm, it should set itself parallel to the direction of the wind however it might blow — showing the upward and downward direction of the wind as well as the horizontal.

A.G.B.

719

1902, June 13 Friday At Beinn Bhreagh Lab. Copied from notes made by George McCurdy, dated 1902, June 5, at Beinn Bhreagh Dark Room, by Jean Safford, Private Secretary. of George Mc Curdy's wire-interior Kite

What is a wire interior kite? And how can we make one? Both these questions I will try and answer in the following pages.

A wire interior kite is one that has a wire interior, as the name shows, and in the case of the kite made this Spring, we used an outside framework of quartered oak, and pianoforte wire for the interior. The wire was used for two purposes, first, to strengthen the kite, and second, that which no kite can do without, viz: — to hold the supporting surfaces.

Now that I have answered the first question, the second comes into consideration. How can we make one? Last year the latter part of November, 1901, the question of making a large, light and strong kite was before the minds of both Mr. Bell and myself. Among other ideas came the one of the wire interior, for there we would get just what we wanted, with only a few disadvantages. Mr. Bell kindly allowed me to build one, and work on it was commenced just after he left in November, 1901.

The nature of such a construction makes the consideration of the outside framework the first thing. Now, in the kite which I planned out, and which I call “The Duma”, the outside framework was composed of oak twelve sided hoops, and oak longitudinal sticks. The kite was shaped like 720 being 400 cm. long and 150 cm. in diameter, tapering at either end until the diameter became only 50 cm. Mr. Ferguson first made the hoops, 17 in all. Each of the hoops had twelve sides, each was made of oak 1 cm. by ½ cm. cross section, the sticks being placed on their edge, and each of the rims had the sticks forming them shoulder jointed, glued and pegged. This made them very strong.

Out of 17 different rims 9 of them were 150 cm. in diameter from opposite corners, the sticks forming the rims being 39 cm. by 1 cm. by 5 cm. The hoops marked (a) being these 9. (See illustration No. 1). They take the position on the largest part of the kite. In photo. No. 2 hoops from (a) to (a) are these same nine.

The two hoops marked (b) (and taking the positions (b), (c) on Photograph No. 2) are made in the same way as the larger hoops. They are 140 cm. from corner to opposite corner, the sticks forming them (in first photo. marked 1,2) being 36.5 long, 1 cm. by .5 cm. cross section. The hoops (c) in photograph No. 1 take the positions marked (c), (c), in Photograph No. 2, are 116 cm. from corner to opposite corner, the sticks being 30.5 cm. long, 1 cm. by .5 cm. cross section. Hoops (d), the letters (d), (d) in photo. No. 2, being the same hoops, are 89 cm. diam. sticks, being 22.5 cm. long. Hoops (e) in Photo. No. 1 being the same in Photo. No. 2, marked (c), (c), are 50 cm. diam. sticks, 12.5 cm. long. The longitudinal sticks (e), (d), (c), (b), (a), (a), (b), (c), (d), (e), 721 in photo No. 2, are each 430 cm. long, 1 cm. by .5 cm. cross section. There are 12 of these. All the rims and 9 of the sticks were made last fall by Mr. Ferguson. Owing to lack of wood the rest were not finished.

Fig. 1

Fig. 2

722

On April 25 work was continued on this structure. The other longitudinal sticks were made, and the core which is 430 cm. long and 1 cm. by 1 cm. cross section. Having constructed the separate portions of the wooden framework, the problem of fastening them together was taken up. This was not such an easy thing to do as I at first supposed. However, we began by tying the longitudinal sticks to the 9 large hoops. Each of these hoops had to be 25 cm. apart. The sticks were tied on the inside of the hoops at the angular points, each stick being on edge, like drawing No. 3 abcd representing a portion of the hoop, and e and f a cross section of the longitudinal sticks. These 9 hoops being all fastened on the longitudinal sticks occupied a space in the center of the sticks of 200 cm., each stick, as I said, being 25 cm. apart. Next came the end rims. The kite with the nine rims was like drawing No. 4 a,b,c,d,e,f, being half longitudinal sticks, g,h,k,m,n,o,p,q,r, the nine 150 cm. diameter hoops.

723

1902, June 14 Saturday At Beinn Bhreagh Lab. Copied from notes made by George McCurdy, dated 1902, June 5, at Beinn Bhreagh Dark Room by Jean Safford, Sec.

Now, the ends of the longitudinal sticks had to be drawn into shape. Accordingly they were all tied by means of a string with the ends 12 cm. apart. This drew them to the required shape. Then the end sticks were put on and tied. The completed outside framework is shown in photograph No. 2. By the way, I forgot to say that the reason for having the longitudinal sticks on the inside of the hoop, was — When the wires are all in the radial wires all pull the hoop in toward the core. Now, the longitudinal sticks, bent in the shape that they are, and having the wire on them as shown in No. 5.

No. 5

form a bow, and the pressure of the bow being in the direction of the arrow. The stick would keep the wires stretched.

After all this comes the important part of stretching the wires. As neither Mr. Ferguson or I had any experience in such matters, we of course, began at the wrong end as our work showed. We began to put in the radial wires, but we found we were pulling the kite all out of shape. Accordingly we dropped that and started on a new plan, which worked all right.

This was to put in cross braces of wire on the outside of the framework. The double lines in Figure No. 6 represent the wooden framework, and the pencil lines the wires. There were 24 in all, and they wound in a spiral form around the kite, at each cross stick taking a double turn. All the wire 724

No. 6.

had to have the temper taken out of it, was too springy to fasten otherwise. However, as there were two strands of wire where this was done, it did not weaken the kite any. This we did by means of an alcohol lamp.

When all the wires were in, I was very much surprised to find how strong the framework was. It was almost as strong that way as it was after the interior wires were in.

After this we found no difficulty in stretching the interior wires as the kite kept its shape. Naturally the radial wires were the next to put in.

These were strung from one corner around the central core to the opposite corner.

725

Fig 7

Let a, e, d, b, f, c, represent the rim; then a wire from (a) would be taken across to the core O, around that and over to (b); a wire from (x) would be taken to the core O, and after going around that would be stretched over to (y), &c. &c. After all of these radial wires were in position came the supporting wires. Figure 7 shows one of the rims after all the wires have been put in place. The lead pencil lines are wires that have only strengthening use. The ink lines are the wires which besides strengthening the structure serve as supports for the cotton.

A glance at the diagram shows that these wires are placed so as to form a number of equilateral triangles having the perpendicular 25 cm. in length.

The dots represent the place where each longitudinal 726 wire runs and all the wires are bound together at this point with soft copper wire. Everyone of the wires were stretched as much as possible while the kite held its form. The wires being all in place, the framework of the kite was finished.

Upon trying the strength of the kite, I found that it could not be bent or distorted in any direction. The whole kite was as a solid block of wood. It surprised me very much.

Now, we had gotten just what we wanted so far, a LARGE LIGHT and STRONG framework. The weight of the kite standing thus was ?

All the wire used excepting the copper wire weighed under a gram a meter, being the best steel pianoforte wire obtainable.

Last of all, and most important, came the putting on of the cotton. The cloth used was fine cotton, weighing 133 gms. per sq. meter. This was torn up into strips 25 cm. wide and a roll made of it. When put on the kite the cotton enclosed a number of cells each 25 cm. every way.

FIGURE 8

727

The way in which the aeroplanes were arranged was as follows: —

Fig. 9

Let the dots in Figure 9 represent the longitudinal wires of the kite. Then a band of cotton was sewed around the wire (a) taken around (f), over (b), around (g), over (c), and then fastened. In the same way was the cotton taken from (k) around over (j), over (m) around (p) and over (n) and back to (k). This was done all through the kite. Then bands four in number, were sewed around the kite, as shown in Figure 10 (a), (b), (c), (d), All the cotton was sewed along the edges, so that there was no part of it left unfastened.

Fig 10

728

FIGURE 11.

Figure 11 shows an end view of the kite finished. Notice the thinness of the edges presented to the wind. This is very advantageous indeed.

FIGURE 12.

Figure 12 is a view of the kite from the side, which shows what the cotton looks like when put on in that way.

729

Before the kite was tried three runners were tied on over three of the longitudinal sticks to prevent any of the hoops from being dragged off when the thing struck the ground. They are the places marked (x), (y), and (z), in Figure 10.

FIGURE 13.

End of notes made by George McCurdy.

J.A.S.

730

1902, August 1 Friday At Beinn Bhreagh

On Wednesday July 30 following modifications of dipping weather vane are suggested in Home Notes, p. 55.

A modified form of cone apparatus we use for measuring the strength of the wind

This led to the following form, which Mr. Ferguson was asked to make

On Thursday morning, July 31, the dippine vane was made by Mr. Ferguson, but the intended small brass arrow-head had been made quite large out of a sheet of aluminum, so that the weather-cock had practically two vanes, one in front and one behind, tending to neutralize one another's action

731

The aluminum arrow-head was then removed — cone balanced by the counterbalancing weight, and apparatus tried in slight NE breeze on the hill

The vane set itself perfectly horizontally in still air but on the hill, where a very slight breeze was perceptible the cone was slightly depressed. There was an occasional vertical oscillation the upper limit hardly exceeding the horizontal. There was also a horizontal oscillation. Wind vane pointed substantially towards the NE, with tail slightly but perceptibly lower than head. My father witnessed the experiment from the new seat erected for his benefit in the laboratory park. The wind was too slight to give a good test to the new wind vane.

The aluminum cone would occasionally dazzle the eyes by reflected sun-light. I have instructed Mr. Ferguson to paint 732 the cone inside and out of a color suitable for photographing — red or black, I think, George McCurdy prefers to white.

733

1902, August 7 Thursday At Beinn Bhreagh LABORATORY INSTRUCTIONS

Take a board 10 in. long, 4 in. wide and ¼ of an in. thick, and cut out at either end two circular discs, A , B each 2 in. in diameter, leaving the board C with a hole at either end

Now, take another board D , of similar dimensions to C (10 × 4 × ¼ inches), and glue on to it the two discs A , B . Bore a hole a ¼ inch diameter through the center of each disc A and B and right through the board D , and insert in these holes brass tubes E , F , 1-½ inches, ¼ inch diameter, as shown below:—

Cut out two circular sheets of thin rubber, at least 3 inches in diameter. Place these over the perforated discs A , B , and fit on the board C , so that the rubber covered discs A , B , fit into the holes in the board, and the rubber sheets, being held firmly between the two boards, C , D 734 are moderately stretched, constituting rubber diaphrams covering the discs A , B . Glue the two boards C , D together, and also screw them together, so that there may be no danger of leak.

Rubber tubes and bulbs will ultimately be fitted on the brass pipes E , F .

Take two boards, 6 inches long, 4 inches wide, ¼ inch thick, and cut into following shape:—

Hinge these over rubber diaphrams as shown:—

735

Cut out four slips of spruce each 6 inches long, ¼th of an inch wide, and #th inch thick, and make of them two crutch like legs, as shown below:—

AGB

739

1902, August 14 Thursday At Beinn Bhreagh.

Mr. Arthur W. McCurdy just told me about developing photographic films on the end of his pier in full sunshine, mixing the developing solution with sea water. He also mixed the hypo solution in the sea water of the Bras D'Or. The result of the developing was a perfect success. Witnessed by Mr. H. Gustav Rogers, of New York, an old plate photographer, who professed to be perfectly non-plussed by this new operation.

Bessie A. Saffud Private Secretary to A. Graham Bell.

M. M c Curdy also told me of this successful experiment with salt yesterday Aug 141 902. AGB Aug 15 1902

740

1902, August 7 Thursday At Beinn Bhreagh. Recollections of Andrew Colville by his grandson Alexander Melville Bell.

The following notes were taken during a conversation on Tuesday evening, August 5, in which some recollections of his Grandfather, Andrew Colville, were given by ALEXANDER MELVILLE BELL

“Andrew Colville, my grandfather, was a very exceptional man. He was one of the geniuses of the world. He was very learned, and although not a professional physician of medicine he was consulted for his knowledge of the human frame, by people all through the district of Fifeshire.

Among other things he was an excellent carver, and I have now a set of bag-pipes, which he made with his own hands, and which I received when I was living in Newfoundland, in 1842.

I remember when he was 90 years of age, I saw him one day on the roof of his barn mending the tiles. When he came down I congratulated him upon his ability to do such work and he remarked “I am a' sund but my legs”.

He married a Miss Steele, Barbara was her first name I think, and had two children — a son named James, and my mother. His wife lived to be quite an old woman, as I remember when she was over 80 years of age and she lived after that.

His son, James Colville, was a doctor of medicine, and became quite prominent. He married and had a large family. I can remember when he died.

The house where my grandfather lived in Fifeshire, was called the Gauldry. I lived in Dundee, but a little 741 distance from the Gauldry, until I was five or six years of age and I used to spend my holiday time there.

It was believed that Andrew Colville was direct heir of the Colville property, but for some reason he never prosecuted his claim, or endeavored to get his rights in the property which was generally known to be legally his.

He died at the age of 94 years."

Recorded by: — Jean Safford, Secretary.

742

1902, August 16 Saturday At B.B.Lab. Experiments & resulting to the use of Compressed in toys.

(Shorthand Dictation by A.G.B.)

Experiments with impulses of compressed air, produced by squeezing a rubber bulb, have surprised me by the force manifested. A diaphram of sheet rubber, 2 inches in diameter, has lifted a mass of lead weighing 10,545 gms., by an impulse of compressed air sent from a small rubber bulb squeezed by the hand.

Abundant power has been manifested for the working of mechanical toys, in the manner suggested in dictated notes, dated 1902, August 7 and 12. I have been anxious to try the effect of a rubber bulb upon a cylinder with a piston in it. George McCurdy has just found a toy engine, that we have had in the Laboratory for some years. No difficulty has been experienced in working the engine by squeezing the rubber bulb, synchronously with the movements of the piston.

A reservoir of compressed air, can be used, of course, in place of the bulb, and a convenient toy be provided for children, which will be perfectly safe for them to handle. Boys are very fond of toy engines, but I cannot think it safe to intrust a small boy with an alcohol lamp and a boiler filled with hot water. We can discard the alcohol lamp, and fill the boiler with compressed air, connecting the boiler by means 743 of a rubber tube, to a rubber bulb, which the boy can hold in his hand, so that when he squeezes the bulb, compressed air is forced into the boiler, and prevented from returning by a valve. A small hole in the tube near the bulb can be covered by the thumb when the bulb is squeezed, and uncovered when it is released. Thus the bulb can be used as a pump by which a boy can pump air into the boiler of his toy engine, and it will then be worked just as though he had a steam boiler and an alcohol lamp, but without the danger .

Acting on the bagpipe principle, we may have a reservoir of air under the arm in the shape of a bag, or better still, in the shape of a pair of bellows, one handle being strapped to the body, the other handle strapped to the left arm, as in the Italian bagpipe. A rubber tube from this bellows led to the piston cylinder of an engine, can cause the engine to move either backwards or forwards. By steady compression upon the bag, compressed air can be supplied to the cylinder, and the engine will move forwards in the normal way.

744

By causing continuous expansion of the bellows, the air in the cylinder will be rarified, and the engine will act by atmospheric pressure backwards. Then, by means of another rubber tube, with a rubber bulb at the end a rudder can be operated by the hand, so that the engine can be both propelled and steered.

745

1902, August 26 Tuesday At Beinn Bhreagh DEFINITION OF FORM OF “HUB” CONNECTING MY “UNIT CELLS”

This constitutes a right pyramid bounded by four equal equilateral plane triangles, one of which constitutes the base.

A pyramid contained by four equal equilateral plane triangles, one of which constitutes the base.

A right pyramid contained by four equal equilateral plane triangles any one of which may be taken as base: — Considered as a crystal it exposes four faces, triangular in form, each the counterpart of the other, and each bounded by an equilateral triangle. It has six edges, four corners, from each of which three edges radiate, the edges make a constant angle of 60° with one another.

A pyramid contained by four equal equilateral plane triangles any one of which may be taken as base.

A pyramid completely contained by four equal equilateral plane triangles:— Placed edge to edge. The figure is 746 thus bounded by six equal straight lines or edges making a constant angle of 60° with one another where they touch. It has four equal triangular faces, three of which may be considered as the sides of the pyramid, and the fourth as the base. Each of these faces constitutes a plane surface bounded by an equilateral triangle. The whole constitutes a right pyramid. Taking any of the triangular sides as base, and the opposite corner as vertex, and drawing a straight line from the vertex to the center of the base as an axis — the axis is perpendicular to the base. The three edges of the pyramid that touch the axis make with it an angle of 30°, and with one another an angle of 60°. Any corner may be taken as vertex, and the same holds true.

What I term my “unit cell” has — ideally — the same form but us not a solid, only the skeleton of a solid — the boundaries or edges of the pyramid referred to above. The unit cell is a pyramidal figure formed by six equal straight lines forming four triangles.

Six equal straight lines constituting the boundaries of four equilateral triangles.

Give a man six matches and tell him to place them end to end so as to form four triangles, and he would think he had quite a puzzling job before him, but let him place three matches on the table so as to form an equilateral triangle and then set up the other three matches like the legs of a tripod camera stand, with their lowed ends 747 in the three corners of the triangle on the table and their upper ends touching one another. He will then find that the six matches constitute the boundaries of four triangles. The resulting form is what I tern my unit cell: — Given six equal straight lines, constituting the boundaries of four triangles, and you have necessarily the form depicted above. You cannot arrange the six matches so as to make four triangles excepting in that way. Why would not this therefore be the best definition of the form of structure constituting my unit cell, and also of the solid pyramid constituting my “Hub”.

A solid figure contained by four triangular surfaces bounded by six equal edges.

A figure formed by six straight lines constituting four triangles.

A completely enclosed figure composed of four triangles formed by the junction of six equal straight lines.

A figure composed of four triangles formed by the junction of six equal straight lines.

In a word: — Form four triangles by means of six equal straight lines and you necessarily have the figure intended. viz: — The “pyramid contained by four equal equilateral plane triangles, any one of which may be taken as base.”

748

1902, August 29 Friday At Beinn Bhreagh & Laboratory Work.

I want to take a brief glance over what we have been doing in the Laboratory with the object of seeing where we are. Things move so slowly from day to day, that it is difficult to note progress during small intervals of time. Laboratory work, roughly, has been divided into three branches: — One branch carried on by Mr. Ferguson under my personal direction; another by Mr. McNeal, under the direction of George McCurdy; and the third by Mr. Zable, with suggestions from me.

1. Mr. Ferguson's work has consisted largely in building larger and larger structures out of the kite material we have, until we now have a kite so large that we have been unable to try it. (See photographs pp. 77–79 Supplement to Vol. IV.). We have no building large enough to store this kite as a whole, and so it has to be stored in pieces and set up in the field when wanted, and after being used taken down and stored away again in pieces. We have already set the kite up with a light breeze blowing, but the breeze died away before we could try it in the air, and it has seemed to me advisable that we should make our first experiment with this kite in a good and sufficient breeze; the only trouble being the difficulty of putting it together in the face of such a breeze as I would like to try it in. The body is 9 M. long (29-½feet) and the superstructure is made of very fragile material, so that it is difficult to handle it without breaking some of the sticks. We have therefore deferred the attempt to fly this kite until we have built a wind break behind whose shelter we can set the kite up, and take it to pieces 749 again. I feel that without a wind break the kite will surely get smashed, because, if the wind is not sufficiently strong to prevent our putting the kite together, it may not be sufficient to support it properly in the air, and we would risk a smash in flying it. On the other hand, if the wind is sufficiently strong to support it well in the air, we would risk a smash in putting it together in the face of such a wind. As the kite has cost several hundred dollars, I don't want to smash it at the first trial, and therefore wait the construction of the wind break.

The construction of larger and larger combinations of cells necessitated attention to the construction of a light and strong framework on which to support the superstructure, and by gradual stages I have been led to the form of body used in the great kite (see photographs pp. 77–79) in which the principle of using triangles in every direction, is attempted to be carried out. The lower part of the kite frame consists of two parallel rods, which form runners, like the runners of a sledge, on which the kite rests when on the ground. This is the only part of the frame in which the triangular form is departed from. Looking at the frame from below it presents somewhat the appearance of a ladder with the rungs at right angles to the runners. It was found upon experiment that this faulty construction permitted twisting of the whole frame, which had to be remedied by bracing wires placed diagonally. The necessity of using bracing wires placed diagonally. The necessity of using bracing wires reveals a structural weakness, and led to the consideration of the desirability of building a frame which shoud be composed of triangles in 750 every direction. The element used in the construction of the body of the giant kite, is practically — a pyramid standing upon a square base and the weakness lay in the square base, which required bracing to prevent twisting. A pyramid upon a triangular base requires no bracing, as I found out practically in experiments in Washington with structures formed of wire triangles tied together with string

I had a large number of pyramidal structures of the above form/made to experiment upon methods of building a compound structure out of such elements. These I termed my “unit cells”, or “skeleton bricks” — comparing them to bricks out of which we might construct a building of any sort. Each unit cell, or skeleton brick consisted of a structure formed by six sticks of equal length placed together so as to form four equilateral triangles

The sticks used were 50 cm. long, 2 cm. wide, 1 cm. thick. The cells were very strong, but difficulties developed in the way of fastening them together into a compound structure. The first experiments were made by cutting off the apex of each 751 pyramid, and substituting for it a circular disc of wood I had about 60 of these skeleton pyramids made, and experimented with them in building up structures by placing them above one another 752 These cells were only loosely fastened together by brads, and yet formed a most surprisingly strong and stiff structure. Each individual cell was too weak to support the weight of a man, but a pyramid as follows was abundantly able to support Mr. Ferguson when seated upon a board upon the top

The board rested upon the summits of three unit cells so that Mr. Ferguson's weight was distributed in the upper section through nine wooden legs, and under these circumstances they were strong enough to support his weight without damage. In the next lower section the weight was distributed among 3 × 9 = 27 legs; the next lower tier of cells 81 wooden legs, so that it becomes obvious that in this form of construction the legs in the basement of your pyramidal building have each to bear a less weight than the sticks in the succeeding stories of the structure — a most important point surely in architecture — the weight is distributed over so large an area at the base that very light material will support an enormous weight. If a pyramidal structure of this kind should be used to support a great weight upon the apex, the heavier material 753 should theoretically be placed at the summit and the lighter material at the base. Supposing the pyramid to be completed to its apex, and the weight placed upon the apex, then the three legs that support that apex must support the whole weight so that each leg must be strong enough to support one third of the weight, but in the next story below the weight is distributed between nine legs, so that each leg need only be strong enough to support one ninth of the weight above that story; in the next story below, each leg would only support one twenty seventh of the weight above; in the next story below one eighty-first of the weight above; in the next story one-two-hundred-and forty-third part of the weight, &c. As we go downwards in the structure the number of supporting legs increases as the powers of 3. The first story at the top, the weight is distributed among 3 legs; in the second story, the number of legs will be equal to the second power of 3; third story to the 3rd power of 3; fourth story to the 4th power, 5th to the 5th, &c., &c.

We have decided to construct our wind break of pyramidal cells, and Mr. Ferguson and I have been at work upon the best way of attaching the cells together, and have made great progress, but I must defer description for a separate dictation, as in this dictation I wish to take a general summary of what we have been doing.

In my opinion the experiments we have made in building larger and larger kites on the cellular principle, have abundantly proved the point that we can increase the size of our kite to an indefinite degree without increasing its flying weight or ratio of weight to surface, and that the larger 754 kites fly as well in a light breeze as smaller kites having the same flying weight (or ratio of weight to surface), so that I see no reason why we should not make a kite of any size by multiplying the number of cells to sustain it.

The giant kite we already have, is large enough to disprove entirely prof. Newcomb's statement: — “That the construction of an aerial vehicle which could carry even a single man from place to place at pleasure requires the discovery of some new metal or some new force”. This kite is large enough to carry a man, and Prof. Newcomb's remarks relating to air ships is specially applicable to kites, because they have no momentum being kept stationary by a cord or string attached to the ground; whereas flying machines having a velocity proper of their own under the action of their propellers will sensibly possess momentum — which in itself may be made a source of support without reference to aeroplanes or other contrivances for gaining support through the resistance of the air. Prof. Neecomb, in his article “Is the Air Ship Coming”, published in McClure's Magazine for September, 1901, takes no account of momentum as a source of support, so that his remarks are much more applicable to stationary bodies like kites than to freely moving bodies not tethered to the ground. The experiments here have demonstrated that, by the adoption of the cellular principle of construction, it is possible to construct a kite of indefinite size which shall be no heavier in proportion to its supporting surface than a smaller kite, and yet be equally strong.

Calculation shows that our large kite, in spite of the heavy body attached to it, will weigh much less thatn 500 gms. 755 per square meter of surface, (my recollection is 466 gms. per sq. M.), so that it should be capable of carrying up a large load in a good breeze — a load equivalent to the weight of a man. I propose therefore to load it and the important question arises where should the load be placed. I have been examining this question with Mr. Ferguson's aid for some time past We have constructed a kite of hexagonal form with two cells and a central stick, which carries a weight whose position can be adjusted on the stick (see pp. 63–64, Supplementary Illustrations) the cells themselves, also can be placed in different positions on the stick

On account of the symetrical arrangement of the surfaces it is assumed that the center of surface of each cell is in the center of the stick, and that the resultant center of surface lies midway between the two cells. The center of gravity also (for the same reason) lies within the central stick, and its position, when the weight is shifted can be ascertained by balancing the whole kite. A number of experiments have been made to test the effect of shifting the center of gravity and noting its position relatively to the center of surface (center of surface, not center of pressure. We can ascertain very easily the location of the center of surface; whereas the location of the center of pressure shifts with the inclination of the kite, but it must bear a constant relation to 756 the center of surface at each given angle of inclination, and the angle of inclination must be controlled by the relation of the center of gravity to the center of surface, so that these two elements, center of gravity and center of surface — both of which can be easily ascertained — and are fixed quite independently of the inclination of the kite — must be correlated together.)

The first problem is: — Should the center of gravity coincide with the center of surface — or be in front of it or behind it — to secure steady flight.

So far the experiments have been indecisive, the weight used, bearing so slight a proportion to the weight of the whole kite that a considerable change in the position of the load has effected only a slight displacement of the center of gravity. We have remedied this by wrapping a sheet of lead around the brass sliding weight, but this has so increased the flying weight of the kite that it requires a good breeze to sustain it, and we have not had at the Laboratory for a long time past — in the afternoons when I am there — a sufficient breeze to test this matter satisfactorily. When we have settled this point definitely, the next point will be to have the center of gravity lower than the center of surface.

I have made many experiments relating to the center of gravity and center of pressure upon kites of other constructions, and have obtained vague ideas as to the result, but I am anxious to supplement these by definite results with a kite of symetrical form, so that we can tell exactly where the center of surface is. So far the impression gained by past 757 experiment is that the center of gravity should very nearly coincide with the center of surface — that this imparts steadiness to the kite — that it should rather be behind the center of surface than in front of it, as this tends to tip the stern down and thus allow the wind to get under the supporting surfaces. Whereas, if the center of gravity is in front of the center of surface there is a tendency for the kite to dive.

Also that the center of gravity should rather be under the center of surface than above, as this secures it against a turning movement that might put the heavy framework above instead of below, in which case the kite would be injured in descending on the ground.

The general impression is that the center of gravity should not be far removed from the center of surface, because of the tendency to swing like a pendulum either horizontally or vertically, which would be inconvenient if not disasterous should there be a man on board. The impression is therefore that the center of gravity should nearly coincide with the center of surface, but be a little below and behind.

2. Mr. McNeal's work under the direction of George McCurdy.

I have been very much surprised at the apparent solicity of the kite constructed for me by George McCurdy before I arrived at Beinn Bhreagh, to test the principle of using stretched piano-forte wire as a support for aeroplanes (see Supplementary Illustrations pp. 6,7,8,9 &c.) This is the kite See also pp. 80,81,82. 758 that he has called the “Duma”. The outer form of the kite is made of thin oak, and the whole thing is kept in shape by interior wire bracing — tightly stretched piano forte wire — the wire not only serves to brace the kite, but it also serves as a support for aeroplanes.

The aeroplane surfaces were so arranged that the kite as a whole does not fly well, but the whole structure is so wonderfully light and strong that it really seemed worth while trying the wire interior principle upon cells properly arranged for flying. Mr. McNeal has therefore been employed under George McCurdy's direction in constructing wire interior cells of a form that we know are well adapted for flying,— the hexagonal form, with six radial aeroplanes — only on account of the large size of these cells (2 M. in diameter) the figures are twelve sided around the circumference, with six radial aeroplanes (see pp. 94, 95, 97, 98) where two of these cells are used at either end of a long body in place of a pole. This body proved to be insufficient in strength and broke under experiment as shown on p. 95. It has since been strengthened as shown on p. 99. Three cells have now been constructed, which were tried the other day in an insufficient breeze, arranged somewhat as follows:—

It was found necessary to load this kite below in order to keep its position in the air. The breeze was not sufficient to give it a fair trial, however, and we shall try it again 759 before doing anything further with the cells.

When two cells alone were used the kite flew beautifully steadily in a very light breeze, although the connecting body was so heavy as to bring the flying weight up to more than 500 gms. per square Meter. The kite flew well as arranged below:—

The cells, themselves, without the body are wonderfully light and strong, flying weight between 200 and 300 gms. per sq. M. (275 ?). These cells are now ready for my experiments.

3. I have not time now to dictate progress in the work intrusted to Mr. Zable, and in reference to it shall simply refer to Dictated Notes, pp. 702 – 715; 733–735; 736– 738; 742–744. A.G.B.

AGB

760

1902, Sept. 9 Tuesday At Beinn Bhreagh

Experiments with wire-interior cells, and remarks concerning utility of wire interior construction.

Since George McCurdy left for Boston I have tried the three celled wire interior kite illustrated on p. 758, flown from the top of the pole in a good breeze, but have made no notes of the results, which were rather unexpected

The kite was attached to the top of the pole by a manilla rope, which was fastened to the bow end of the central core, as shown above — that is in the same line with the center of surface. Stout cod lines were attached to the bow and stern as shown, for handling. The wooden framework extending below made the center of gravity very slightly below the center of surface, the kite however turned on one side and finally flew upside down

The framework extending below the body was then loaded with a sheet of lead wrapped round one of the sticks, equivalent 761 to a load of about 3000 or 4000 grammes. In this case also the kite first turned on its side and then turned completely over, flying with the loaded end up in the air

In this case (3) the center of gravity was certainly above the center of figure. In trying to fly the kite by the cod line attached to the bow, the strain was found to be too great and the cod line broke, leaving the kite flying from the pole by the manilla rope alone at the bow. We tried to get the kite down by pulling on the stern line. In this case also the strain proved to be too great for the cod line used and it broke, so that we were in a dilemma how to bring the kite down. The problem was solved for us by the bursting of the stern cell, which gave way under the action of the wind. This allowed the stern to come down sufficiently far to be caught by the men.

This reveals one defect and a serious one possessed by wire interior cells. The breaking of one stick on the circumference involves the complete collapse of the whole cell; whereas a cell built up of wooden frames arranged on the triangular 762 plan is not materially injured by the breaking of a stick. The aeroplane supported by that stick may be wrecked but the remainder of the cell remains uninjured, and the broken stick can easily be replaced making the whole frame as good as before. But the breaking of one of the sticks of a wire interior cell causes the complete collapse of the whole cell and it is extremely difficult to repair damages. This should be taken into consideration in utilizing this form of structure.

Under the action of a strong wind the kite emitted the most extraordinary noises caused by the vibration of the aeroplanes supported by the stretched wires, the wires being elastic give to a certain extent causing the aeroplanes to flutter at their rear edges.

On the whole I am a little doubtful as to the expediency of adopting the wire interior plan in toto . We are certainly able to build up an exceedingly light and strong structure but if anything happens to our exterior — and it is always thr exterior that comes in contact with obstacles — the whole thing goes. It is like a leak in the Magdeburg hemispheres. So long as there is a partial vacuum within they stick together with great force — but a pin hole would be fatal.

In the wire interior we utilize the enormous tensile strength of fine steel wire; but this wire has practically no compressional strength. It offers great resistence to a pull, but very little to a push. The enormous tensional strength of the steel wire combined with its light weight certainly indicates that it may be used to great advantage in kite structures.

I am inclined to think, however, that it 763 would be better to combine it with material possessing compressional resistance and lacking tensional strength, rather than rely upon an interior possessing tensional strength alone. It can certainly be used to tie together materials (wood for example) which possess compressional strength. A triangle of wood, for example, would be very much strengthened if bound round with steel wire; the wooden part resists compression and the steel part resists extension, so that the two combined are better than either separate, and the steel wire is so light as to add very little to the weight.

I think that George McCurdy has been too anxious to secure great lightness of construction. The outside rims are made of wood 1 cm. wide and ½ cm. thick, and the whole cell 2 M. in diameter has a flying weight of between 200 and 300 grammes per sq. M. of surface. Now we could build up a good solid cell of similar construction of wood alone which would have a low flying weight (less than 400 gms. per sq. M.) without the wire at all. The wire is so light and strong that it enables us to do away with the interior framework of wood. Why not, then make the exterior framework heavier and stouter . It is not necessary to reduce the flying weight because the one of wood flies perfectly well. We could afford to double the thickness of the circumferential sticks if the wire alone is used in the inside, and yet have no heavier kite than with wood alone. In this case would not the resulting structure be much stronger than the wooden structure. The only danger 764 is that the giving away of a single stick on the outside involves the destruction of the whole structure. It is like a chain — which is no stronger than its weakest link — still where the weakest links are strong, chains can be made of great use, and though the wire interior cell is no stronger than its weakest stick, — by making the weakest stick stout and strong the whole may be of great use.

Then, again, it is not absolutely necessary to have aeroplanes on the interior.

Diminished rates of weight to surface in compound cellular structures of large size.

In combining together three triangular kites we obtain a structure that weighs just three times one kite and has three times the surface, and by omitting one longitudinal stick where two come together a saving of weight is effected so that the compound kite, while exposing three times the surface of one kite weighs less than three times its weight.

In this structure the proportionate weight saved is very slight, while there is no increase of surface by the combination. If now we were to cover the ends of the kite instead of the sides we should have an enormous gain for example

Fig.1

Fig. 2

765

For example; three triangular frames covered with cloth give support to three aeroplanes if separate as shown in Fig. 1; but when combined as in Fig. II 2 they form an equally strong support for four aeroplanes, so that in such an arrangement we have the framework supporting four aeroplanes weighing no more than the frame for three if separate.

If we adopt the skeleton pyramid as the strongest form of structure, still more remarkable advantages arise through combination

Fig. 3

Fig. 4

Fig. 5

In Fig. 3 the skeleton pyramid shown has its base covered with cloth, constituting an aeroplane. In Fig. 4 three such skeleton figures support four aeroplanes at the base; but the apices of the pyramid can form the support for a triangle which may be covered with cloth so as to constitute a fifth aeroplane, as in Fig. 5. Thus in the arrangement shown in Fig. 5 we have five times the aeroplane surface shown in Fig. 3 supported by a frame only three and a half times as heavy (3 pyramids and 1 triangle). The flying weight of the compound structure is very much less than that of the original structure Fig. 3, but the structure itself is equally strong. Every increase in combination reduces the flying weight without diminishing the strength of the structure.

Fig. 6

Fig. 7

766

For example, the structure shown in Fig. 6 is composed of ten skeleton pyramids like that in Fig. 3, and the apices are connected by the triangular framework shown in Fig. 7, consisting of 6 triangles (equal in weight to 3 pyramidal frames. Thus the weight of the whole structure is equivalent to 13 pyramids like Fig. 3, while the supporting surfaces are — on the base of Fig. 6 a surface equal to 16 triangles like the base of Fig. 3,—and the upper surface formed by the frames connecting the apices of the pyramids in Fig. 6 make another aeroplane surface, see Fig. 7, equivalent to 9 triangles like the base of Fig. 3.

Comparing this combination therefore with Fig. 3 we have a structure having 25 times the aeroplane surface, the framework of which weighs only 13 times as much. This structure gives us two superposed aeroplanes parallel to one another, and it is obvious that we can build upwards to any extent, pyramid above pyramid and thus get parallel superposed aeroplanes to any extent with a decrease of flying weight without loss of strength in the structure.

The unit aeroplane surface above considered is triangular in form and the larger aeroplane surfaces are also triangular in form; but it is by no means necessary that the triangular form be retained for large aeroplanes — compound. For example, here is a structure supporting two superposed aeroplanes having parallel sides, like the aeroplanes of an ordinary Hargrave kite; but the upper aeroplane has only half the width of the lower.

9 Pyramids

at base 6 sticks =1 Pyramids.

at 15 sticks = 2½ Pyramids

weight & whole frame = 12 ½ Pyramids

Fig. 8

Fig. 9

767

The structure consists of 9 skeleton pyramids like that shown in Fig. 3 connected together at the bases by six sticks to complete the form as shown in Fig. 8, and connected together at the apices by the triangular framework shown in Fig. 9. As each pyramidal frame consists of 6 sticks, we can calculate the whole weight of the compound structure in pyramids like that shown in Fig. 3 by assigning 6 sticks equal one pyramid. The weight of the whole structure then is equivalent to the weight of 12 ½ skeleton pyramids, like that shown in Fig. 3, while the surface is equivalent to 25 triangles like the base of Fig. 3; so here we have a structure, exposing 25 times the surface, and weighing only 12 ½ times as much as the structure in Fig. 3.

AGB

768

1902, September 11 Thursday At Beinn Bhreagh Upon the great weight that may be allowed to the structure of a Flying-machine.

In Means Aeronautical Annual for 1897, No. 3, p. 42 Mr. Chanute gives some account of experiments with a gliding machine, the sustaining surface being 135 sq. ft., and he says: —

“This was thereafter found ample to sustain an aggregate weight of 178 lbs. (23 lbs. of machine and 155 lbs. of operator), and all the subsequent experiments were made with this arrangement. During the next 14 days scores and scores of glides were made with this machine whenever the wind served. It was fo ound steady, easy to handle before starting, and under good control when under way.— a motion of the operator's body of not over 2 inches proving as effective as a motion of 5 or more inches in the Lilianthal machine. It was experimented in all sorts of winds, from 10 to 31 miles an hour, the latter being believed to be a higher wind than any gliding machine had been tried in theretofore, and yet the equilibrium was not compromised, the machine gliding steadily at speed of about 17 miles per hour, with reference to the ground, and of about 20 to 40 miles an hour with reference to the air or relative wind”. &c.

135 sq. ft. = 12.5 sq. M.; 178 lbs = 80812 grammes The Flying weight of the gliding machine that was “found ample” to sustain this weight was:—

6465 grammes per sq. M.

By actual experiment a sustaining surface of 12.5 sq. M. was “ample” to support a man in the air in a gliding machine — and therefore a flying machine. In my apparatus I am calculating upon more than 150 sq. M. to support the same weight.

I aim to have the machine weigh about 400 gms. per sq.M. 769 and find this perfectly practicable. But in this satisfactory gliding machine of Chanute's the machine weighed 10442 gms. (23 lbs.) with a sustaining surface of 12.5 sq. M. That is: — The machine weighed 835 gms. per sq. M. of surface and was satisfactory. From this it would seem to follow that I could double the weight of my materials. I now aim for 400 gms. per sq. M. —

if I allow 800 gms per sq. M. there would be no flimsy construction about my machine at all.

I am surprised at the large proportionate weights used, or allowed rather, by Chanute and by Hargrave.

Hargrave estimates a flying weight of 1 lb. per sq. ft. of surface, that is 4885 gms. per sq. M. Surely then I am scrimping myself unnecessarily in limiting the weight of my machine to 400 gms. per sq. M. Both Hargrave and Chanute impress me as reliable men, and they consider as practicable a weight of from 5000 to 6000 gms. per sq. M.

Hargrave 4885 gms. per sq. M.

Chanute 6465 gms. per sq. M.

A.G.B. 400 gms. per sq. M. (without load)

It is obvious that I can double or treble the weight of my framework and yet come far within the limits of a practicable flying machine. The pyramidal style of construction is so strong, with little weight, that the whole thing may be made of metal — even steel —.

Using aluminum alloy having a specific gravity of 2.5 770 we can make the sides of our skeleton pyramids 50 cm. long 1 cm. wide and 1 mm. thick. — bending the slip of metal like an umbrella rib to give it greater strength in every direction

These slips can be riveted together forming pyramidal cells having a side of 50 cm. and the whole structure will weigh only 298 gms. per sq. M. (see Home Notes, Sept. 10, 1902, p. 155).

Or let these slips be only 25 cm. long so as to build up into pyramidal cells having 25 cm. on a side. The flying weight of the frame would be 596 grammes per sq. M. (Home Notes p. 155).

If the 50 cm. pyramids are made of steel of the same dimensions (with specific gravity of 7.5) the structure would weigh 894 gms. per sq. M. (this is an under estimate, for I think specific gravity of steel is greater than that, from 7.8 to 8).

By adopting the pyramidal structure and the 50 cm. pyramid, we could make a frame much stronger than our wooden frames, weighing not more than 300 gms. per sq. M., and use aluminum foil at 100 gms. per sq. M. for the sustaining surfaces.

771

The Pittsburgh Reduction Co. sent to me in Washington specimens of aluminum alloy upon which the above calculations are based. One specimen of foil that would do weighed not more than 100 gms. per sq. M. — but, in order to be sure of having a satisfactory metallic surface for an aeroplane, let us double its thickness and allow 200 gms. per sq. M. for the foil. This brings the total flying weight up to 500 gms. per sq. M.

We can make the whole thing of aluminum alloy without exceeding this weight and have a structure resisting compression as well as our present wooden structures, and having a tensional strength almost infinitely superior.

But the figures of Chanute, Hargrave and others, show that we can allow a very much greater weight for the structure than here indicated. Instead of 500 gms. per sq. M. let us allow 1000 gms. per sq. M. for the machine and we will have a solid structure made wholly of metal, fit for any purpose we desire.

In a practicable flying machine a motive power will be used that will give the machine a velocity of its own in calm air. Santos Dumont was able to give his airship a speed of “not less than 8 M. a second” (26 feet) — or 17.7 miles per hour. The same propelling power applied to a machine made with aeroplanes, and omitting the resistance of the gas bag would certainly produce a very much higher velocity. It seems certain that we can rely upon motors that will drive 772 an aeroplane machine at least 20 or 25 miles an hour.

I have aimed to produce a structure that will fly in a very light breeze, and so come down gently even in a calm, without propelling power. I have found that our kites fly well in a breeze of about 4 ½ M. per second or 10 miles an hour. Whatever weight they would support in such a breeze (including their own weight) they would support 4 times that weight if the velocity of the wind were doubled so as to be 20 miles an hour. I feel that I have been too anxious to make a structure that will fly in a light breeze. Such a structure must necessarily be light itself and therefore, if flown in a heavy breeze, or — what is the same thing driven at a rapid rate through the air — the structure would be unnecessarily strained — a butterfly cannot fly in a hurricane, and the light flying machines would be torn all to pieces if propelled with the velocity of a railroad train. A practicable machine MUST be capable of being driven at a good speed through the air, say at least 25 miles an hour (or 11 M. per second). We can make such a machine entirely of metal — aeroplanes and all.

The only value of a light structure is to enable the machine to come down very slowly, so as to light gently. It is for safety alone and is not advantageous for speed or for any of the qualities that go up to make a flying machine. Lightness of structure bears the same relation to the flying 773 machine that a parachute does to a balloon — or a life preserver to a swimmer. The one does not aid the balloon to go up, the other does not aid the swimmer to swim. The swimmer has learned to discard the life preserver with advantage — the balloonist leaves his parachute behind.

Make the flying machine heavy — of solid metal — and if we must add the light structure for safety in coming down let it be an addition and not an integral part of the machine Let the machine carry a light structure that can be unfolded when you want to make a gentle descent, and closed out of the way while executing manoeuvres in the air, as the beetle carries his light wings inside a hard casing. Then, after executing manoeuvres in the air you want to descend — reduce your headway and open your light wings, throw out an anchor and fly as a kite in a light breeze, or glide gently down to earth or water.

My experiments show there is no difficulty about a light framework. They also show that it is easily ripped to pieces in a strong wind. Let us make the kites of strong material to stand a strong wind, and add on light material to support them in a gentle breeze that can be reefed or folded away when the strong breeze comes. Aim for a machine that will fly well in a breeze of 20 miles an hour, for such a structure should fly well as a flying machine under the action of its own propellers propelled at the rate of 20 miles an hour, and all experiments with dirigible balloons, &c. show that this speed can certainly be obtained with motors that are now in the market. A.G.B.

774

1902, September 23 Tuesday At Beinn Bhreagh

Cells symmetrical in respect to their centers are indifferent to their position in flight, for example triangular cells (equilateral) square cells, hexagonal cells, circular cells, seem to be in equilibrium in whatever position they happen to be in the air. The same is true of radial winged kites with three, four, five, six or more radial wings.

In compound kites of a cellular structure the triangular form of cell has been adopted, and it seems to me that the compound structure composed of equilateral triangular cells — where symmetrical around a center — is also in equilibrium in any position it may be in the air.

In order to make such kites keep right side up it has therefore been my custom to make that portion of the kite intended to be below of stouter and heavier material than the upper part “the superstructure” — that is: — We try to obtain stability of position by loading the kite on the lower part. This means that the center of gravity is below the center of surface. There is one grave objection to this — a pendulum action is apt to be set up. The center of gravity constituting the bob of the pendulum, and the center of surface (or center of pressure) constituting the axis of oscillation. The lower the center of gravity in respect to the center of surface the greater the amplitude of oscillation, so that theoretically the center of gravity should be as little as possible below the center of surface. But this is opposed to the principle of gaining stability by weight. The more nearly the center of gravity comes to the center of surface the more easily would the whole apparatus be upset by a squall 775 It is like the ballast of a sail boat — the lower the center of gravity of the boat can be brought the more will it resist the tipping action of the wind.

I am a little inclined to believe that the whole principle of gaining stability by weight is false — in the same way that the principle of preventing a sail boat from tipping by loading the keel is false — as it corrects one error by adding another. It would be better to apply wind power to a boat in such a way that it would not tend to tip it over at all than to load it down with unnecessary weight, and so it would be better to secure the equilibrium of a kite in the air by its form rather than depend upon an eccentric weight for stability.

Theoretically the center of gravity should coincide with the center of surface (or center of pressure), and the kite should be so formed as to resist a turning action independently of its weight.

Take a compound kite of triangular construction intended to fly in the position shown in the following diagram

776

Now, let the cell tip over to one side so that the line de becomes vertical. Now all the aeroplanes parallel to de are vertical and do not support at all, and the aeroplanes parallel to be become more and more horizontal as the kite tips over, so that they support more and more. But, those aeroplanes (parallel to be) which are to the right of the vertical de alone tend to right the kite. Those on the left of be de tending to upset it still more. In the following diagram the bc aeroplanes that tend to restore the kite to its original position are darkened.

On the other hand, should the kite tip over to the other side so that df becomes vertical, then all the bc aeroplanes are vertical and do not help to restore the position, and the only aeroplanes of the ac set that help to right the kite are those to the left of df . The surfaces parallel to ab we may consider as supporting surfaces, and the surfaces parallel to ac and bc — though they do support to a certain degree — on account of their angle — yet have as their chief function 777 a steadying action to cause the ab aeroplanes to become again horizontal should the kite from any cause tip to one or the other side. Certain portions of these oblique aeroplanes are useful for this purpose, other portions are not of any help and indeed are worse than useless in this connection because they oppose and neutralize the action of the useful parts.

Considering then the horizontal surfaces as alone the support of the kite, and the oblique surfaces as steadiers pure and simple, the following diagram gives the useful aeroplanes in dark lines and the aeroplanes that might profitably be omitted in light lines.

It is obvious that a large part of the structure (in light lines) not being required for the support of aeroplanes might with advantage be removed. The following forms seem to me to retain a large part of the structure useful for the support of aeroplanes, and to omit a large part which could not profitably be used

778

These seem to me all self righting forms. For example let us take extreme cases of one of them. Let it be in position as follows to dive directly sideways with a disasterous smash to the earth

The supporting surfaces being verticle no longer support, and the kite tends to fall end side on to the ground. But the oblique steadying surfaces below the center c cause the lower end to turn to the right while the oblique surfaces above the center c cause the upper end to turn to the left. The supporting surfaces begin to support as the kite turns, but they neither help nor oppose the turning movement— T t he supporting surfaces on either side of the center c being the same. The kite will then turn until it comes into the normal position with the supporting surfaces horizontal. It may, from the momentum gained tip over somewhat to the other side, but whenever it departs from the horizontal position the oblique surfaces act so as to turn it back, so that the turning momentum of the kite would be soon frittered away by the retarding action of the oblique aeroplanes, so that the kite would oscillate about its position of equilibrium for a short period of time with lessening amplitude of vibration, so that it would ultimately settle down with the supporting surfaces horizontal.

Take another case. Turn the whole kite upside down 779 and surely this is an extreme case

This is a case of unstable equilibrium like balancing a walking cane upon the finger So long as the supporting surfaces are horizontal the turning pressures are balanced. But let the thing tip ever so little, then the oblique aeroplanes on the higher side lift more than they did before, and those on the lower side lift less, so that a turning movement once initiated would be continued by the action of the oblique aeroplanes, until the position shown on p. 778 is reached when the kite would turn completely over and be restored to its original horizontal position.

While the cellular construction of frame should be retained in order to get an extremely solid as well as light structure, we should while completely covering the horizontal frames upon which we rely for support, cover only those oblique frames which slope downwards towards the central line of the kite, and avoid covering those that slope downwards away from the center.

I am particularly struck with the adaptability of the following form for a flying machine 780 which consists essentially of two compound triangular cells with aeroplanes arranged on the above principle, and a center triangle without aeroplanes in which may be placed men and machinery, &c. The center of gravity can easily be made to coincide with the center of surface in this case. Still more advantageous — in some respects — would be the same arrangement upside down, the oblique aeroplanes being arranged as shown in the following figure.

In this case the structure is well adapted to float on the water, which would be an element of safety. While, in the air, any bullet in order to reach the man or machinery in the interior would have to pass through a number of horizontal and oblique aeroplanes, some of which at all events would be presented obliquely to the impact of the bullets. Even with silk or cloth it sould be very difficult for a bullet to reach the interior without being deflected very considerably from its path, while, if — as I propose—the surfaces — especially of the under part — should be made of aluminum alloy and the V shaped portion at the bottom of the man cell should be made of hardened steel, it would practically be impossible for the man inside to be injured — an important consideration when we view the use of such an apparatus in warfare.

AGB

781

1902, September 24 Wednesday At Beinn Bhreagh

I now see my way clearly to the construction of a kite framework and aero-surfaces (plane or curved) entirely of metal that will fly in a wind of moderate velocity and be capable of carrying a load equivalent to a man and an engine. The only question in my mind has been where should the load be placed with reference to the supporting surfaces.

The conditions in a kite are somewhat different from those in a flying machine. With Cellular structures so constructed that they are indifferent to their position in their air, it has been necessary to place the center of gravity below the center of surface in order to secure stability, and yet, it must be very slightly below the surface to avoid a pendulum action. It has also been advisable to place the center of gravity slightly behind the center of surface, which tends to depress the stern and thus place the supporting surfaces to a slight angle to the wind. Reducing the kite to its theoretical elements we have the center of surface upon which the wind acts, so as to produce two elements — lift and drift. Upon lift depends the support of the whole machine in the air. Drift is an undesirable element. Eliminate it as much as possible by having the supporting surfaces as near the horizontal as possible, the drift element increasing with the inclination of the supporting surfaces. So the really important element connected with wind pressure is the lift, or vertical component of wind pressure. I think it advisable to consider this as applied at the center of surface because this 782 is a fixed point that can be readily determined. The actual center of pressure varies with the inclination of the kite, and I do not know how to ascertain its position theoretically.

In a kite then we have the lift applied at some theoretical point in the kite, and it is obvious that this lift acting upwards must balance the downward pressure a rising from the weight of the kite and from the tension of the cord that connects it with the ground. The pull of the cord is applied at some fixed point in the kite and consists of two elements, a downward pull equivalent to an additional weight, and a horizontal pull which is exactly equal and opposite to the drift element of the kite. The lift, also, is exactly equal and opposite to the sum of the downward pressures, viz: — the weight of the kite plus the downward pull of the string. We have here two sets of balanced forces: —

1. Drift = the horizontal pull of the string.

2. Lift = the weight + the downward pull of the string.

In a condition of equilibrium the center of downward pressure (weight and downward pull of the string) must evidently be in the same vertical line with the center of lift. If this resultant point is above the center of lift, there is unstable equilibrium. If it is at the center of lift there is indifferent equilibrium. If it is at the center of lift there is indifferent equilibrium. If it is below the center of lift there is stable equilibrium. So that, where the surfaces are so arranged that the kite has no tendency on account of its form to assume one position more than another, the resultant of weight and downward pull must be below the center of lift.

783

That is the center of gravity, or the point of attachment of the string, one or both, must be below the center of lift and should one of these elements be above the center of lift, the lower one must exceed in magnitude the upper one in order to bring the resultant of the two below the center of gravity.

As the center of gravity should theoretically be — in such a case — slightly behind the center of lift — the point of attachment of the string must necessarily be in front of the center of lift.

So that as I conceive our kite in its present condition where it depends for stability upon weight and not upon form, it consists essentially of a center of wind pressure, a center of gravity below and slightly behind, and a point of attachment for the string below and in front. If the string were cut so as to convert the kite into a free flying machine, it would be necessary to load the kite in front with a weight equivalent to the downward pull of the string and placed so that the center of gravity below should occupy the point of attachment of the string.

Everything is grouped about the center of wind pressure, and the machine would have to be provided with some form of propeller to take the place of the horizontal pull of the string. It would be a push instead of a pull, and the center of propeller push should be in the same horizontal line with the center of wind pressure.

Now, all the difficulties connected with a loaded kite or a loaded flying machine lie in the ex-centric arrangement of the forces concerned, leading to oscillation of greater or less magnitude.

784

Theoretically the resultants of all the forces concerned should meet in the same point.

But, both in a kite and in a flying machine a condition of equilibrium is needed such that the machine shall retain a constant position in relation to the earth. We must not have a condition of indifferent equilibrium, for it would certainly be most unfortunate for the bottom of the machine suddenly through the action of a squall become the top <u>and remain so.</u> We cannot control the wind, and its action is of all things the most irregular. We must reconcile ourselves to the fact that changes of position will occur and we must so construct our machine that it will right itself automatically. It seems to me therefore that an arrangement of aeroplanes or surfaces that will float on the air <u>only one way</u> tending to return to the normal position whenever disturbed — is of the greatest consequence, as, giving the machine a power of self righting independently of weight. We may help and confirm this position of stability by having the center of gravity very slightly below the center of surface — but it should not be much below.

I constructed last night a kite embodying the principles elaborated pp. 776 to 780, as follows

785

For the sake of a clearness I have omitted the triangular construction so as only to show the aeroplane surfaces. There were two cells connected by three sticks so arranged that (at least theoretically) the center of gravity of the whole kite coincided with the center of surface. The string was attached to the center stick as shown. On account of the omission of so much aeroplane surface while retaining the empty frames for the sake of solidity of construction, the flying weight of this kite was quite high in comparison with our standard of 400 gms. per sq. M. The flying weight was if I remember rightly, about 670 gms. per sq. M. of surface. There was no wind when the kite was completed, but the kite flew beautifully and steadily when Mr. Zable walked with the string, showing that it will fly in a very light breeze. When he stopped the kite came down very gently and steadily without any oscillation, and landed horizontally upon the grass as lightly apparantly as though it had been fully equipped with the missing aeroplanes.

I can hear a good breeze blowing outside now — in fact it seems to be blowing up for a gale, so I will stop this dictation and go down to the laboratory to try this form of kite in a wind that is certainly too strong for such a light structure. I am specially anxious to fly this kite upside down at a considerable elevation to find out whether the self-righting feature is really there. Unfortunately I don't see how to attach the cord at a point in the same horizontal line with the center of gravity and center of pressure, and so the best way to 786 test the self-righting feature will be to fly it upside down by a bridle to a considerable height, then cut the string and see whether the kite will right itself in falling.

I will ask Miss Safford to copy a few diagrams from Home Notes that I have not time now to expand.

I would like to dictate something about the following drawings and will do so later on

787

(Copied from Home Notes p. 179 dated 1902, Sept. 22, Monday).

(Copied from Home Notes p. 180 dated 1902, Sept. 22)

788

(Copied from Home Notes p.162, dated 1902 Sept. 11, Thurs.)

(Copied from Home Notes p.176, dated 1902, Sept. 21, Sunday)

Corrugated in triangle stamped grooves

Make one series of parallel groves

Then another series at 60° to first

Then a Third series or stamps whole thing at one operation

789

(Copied from Home Notes p. 179 dated 1902, Sept.22, Mon.)

(The drawings on pp. 787, 788, 789 copied by me, J.A.S.,Sec.)

790

1902, Oct. 16 Thurs. At Beinn Bhreagh

I find it very difficult to obtain tables showing the normal pressure of the wind against a surface normally opposed to it. This of course would be the maximum pressure possible for a given wind velocity.

I find it necessary, therefore to construct a table for my own use, which will give me some idea of the normal pressure of the wind upon a surface at right angles to it — with this certainty — that the actual pressure will be greater than that given in the table — at least if my basis of calculation is correct.

Davis, in his Elementary Meteorology, p. 94, gives a table relating to the velocity and pressure of the wind. From this I find that velocity of 5 M. per Sec. yields a pressure of 3.15 Kilogms. per Sq. M.

If, as we have every reason to believe, the pressure varies directly as the square of the velocity, this would yield a pressure of 126 gms. per Sq. M., with a velocity of 1 M. per Sec.

In the same table Davis gives the velocity of the wind in the most violent hurricane as 42 M. per Sec., and states that this results in a pressure of 222 Kilogms. per Sq.M. Calculation shows that this corresponds to a pressure of 125.8 gms. per Sq. M. with a velocity of 1 M. per sec.

On the whole, Davis's table is consistent with a basis of 126 gms. per sq. M. with a wind velocity of 1 M. per sec. In order to be within the mark we will assume 125 gms. per sq. M. in the following table.

791

TABLE OF WIND PRESSURES

Velocity of wind in meters per sec.	Pressure on 1 Sq. M. of Surface		
	Assumed	Assumed	Davis's Figures
1 M per sec.	100 gms.	125 gms.	126 gms.
2 “	400 “	500 “	504 “
3 “	900 “	1125 “	1134 “
4 “	1600 “	2000 “	2016 “
5 “	2500 “	3125 “	3150 “
6 “	3600 “	4500 “	4536 “
7 “	4900 “	6125 “	6174 “
8 “	6400 “	8000 “	8064 “
9 “	8100 “	10125 “	10206 “
10 “	10000 “	12500 “	12600 “

HANDY RULES TO CONVERT MILES PER HOUR INTO FEET OR METERS PER SECOND

1. Add on half the number of miles and call the answer feet

Example: — 10 miles per hour how many ft. per sec. ? 10 + 5 = 15. (15 ft. per sec. approximately.)

2. Halve the number of miles and call them meters per second.

Example: 10 miles an hour how many M. per sec.? 10 + 2 = 5. (5 M. per sec. approximately).

1 M. = 3.280899 ft. (3-¼ ft. approximately).

1 Sq. M. = 10.7649 + Sq. Ft. (10-¾ sq. ft. Approx.)

792

One of the aims I have in view is to construct a kite that — when loaded with the equivalent weight of a man and engine — will come down when cut loose so gently that there would be no danger to life or limb with a living being aboard, so that, when such a kite should be converted into a flying machine, the failure of the engine to act — or the propellers to work — would not involve a CATASTROPHE.

This means that the kite, when loaded should be able to fly in quite a moderate breeze — certainly in a breeze of 10 miles per hour, or 5 M. per sec. A kite weighing not more than about 400 gms. per Sq. M. of surface, comes down like a feather. Such a kite carrying a load equal to its own weight comes down uninjured, even when made of very fragile material, in so gentle a breeze that it can hardly be felt on the surface.

A kite weighing 292 gms., and loaded with a brass rod weighing 411 gms., making a total weight of 703 gms. (or 937+ gms. per sq. M.), flew well in almost a calm when a man ran with the cord, and came down gently without injury when he ceased running. (See these notes Vol. II, p. 427). I estimated the velocity of the man as 4-½ M. per sec., and I presume that the velocity of the kite relatively to the air exceeded 5 M. per sec. when the man ran in one direction, and less than 4 M. per sec. when he ran in the other direction. (In both of these cases the kite supported itself).

793

From this and other experiments, I have received the idea that a kite weighing (with its load) not more than 1000 gms per sq. M. of surface, will fly well in a light breeze say of 5 M. per sec. and come down gently.

In this case the weight of the kite is about # of the theoretical pressure of the wind acting normally on the surfaces involved — that is at acting vertically or at right angles to the surfaces —

This means that if we can construct a flying machine upon the model of our kite that will weigh with its engine, propellers and man not more than 1 Kilogm. per sq. M. of surface, it will fly well in a calm when propelled at a rate of 10 miles an hour (or 5 M. per sec.) and come down gently should the engine or propellers fail to work.

My experiments abundantly demonstrate that this can be done. If we can rely upon our engines and propellers — as of course we will do when flying machines have become practicable, and we have gained knowledge by experience — we may certainly count upon a speed of 20 miles an hour or 10 M. a sec. for this has actually been accomplished (I understand) by Santos Dumont, notwithstanding the enormous resistance of his balloon attachment. With such a velocity we could afford to allow more than 4,000 gms. per sq. M. of surface which would enable the machine to be made of good solid material. I think, however, that in the first experiments with men on board we should aim for a structure that will come down very gently upon water in a calm in the event of any accident to the machinery. 794 And it would be well, therefore, at first not to exceed 1000 gms per sq. M. of surface load and everything included.

One of the main points I have been working on for some time past has been the development of a form of structure involving the maximum of strength with the minimum of weight. The adoption of a triangular element has been an enormous improvement. Rectangular cells are always rickety in construction until they are braced internally either by cross wires or cross sticks. The triangular form of cell on the other hand, is perfectly braced without the necessity of employing internal bracing of any kind. This is of enormous importance because internal bracing opposes an additional resistance to the wind,— which is unnecessary and undesirable if the structure can be made solid without it —

The triangular kites, however, proved to be rickety longitudinally, but this was not of so much consequence because the internal bracing required did not come in the way of the wind. Still, the necessity of guy wires or oblique sticks to strengthen the frame work longitudinally and prevent twisting (which causes the kite to steer itself round in a vertical circle in the air; twisting up the string) led to the consideration whether it might not be possible to adopt the triangular structure longitudinally as well as transversely.

This led to the conception of an elemental structure composed exclusively of equilateral triangles. It constitutes the skeleton of a “regular tetrahedron”, — a solid bounded 795 by four equilateral triangles, having six equal edges with faces meeting at 70° 32# and four trigonal angles. The principal axes join the middle points of each two opposite edges. Examples are found in such minerals as fahlore, boracite, and helvine. (see Encyc. Brit. Article Mineralogy; Figs. 47 & 203).

While little difficulty was experienced in making frames of this form — the sticks or wires employed corresponding to the edges of the tetrahedron — considerable difficulty was experienced in devising a suitable means of attaching the frames together into a compound structure, — and I found it quite beyond my powers to draw a compound structure that could be made at once without building it up of individual or unit frames or cells.

I had a number of experimental frames made of wood with discs upon their summits, so that they could be made to stand one on top of the other and combined in various ways. In this way I was enabled to study the character of the compound structures that could be built up of such elements.

The following photograph shows a skeleton tetrahedron built up from 10 of the smaller frames. The first story of the picture consists of 6 frames standing side by side as follows: —

796

The second story is formed of three frames standing on the summits of the pyramidal frames constituting the first floor; the third story consists of one frame standing on the second story, thus completing the compound structure which is itself the skeleton of a regular tetrahedron like its constituents.

The second photograph shows the elemental frames piled away for storage.

The two photographs on the next page show 4 frames combined and screwed together, so that the resulting structure can be lifted without the elements falling apart. The young lady 797 is Miss Sarah Marsh, daughter of Dr. Elias J. Marsh of Paterson, New Jersey.

798

The following photograph shows Miss Sarah Marsh holding in her hands a skeleton tetrahedron made (by Miss Safford) from six strips of aluminum alloy each 25 cm. long, 1 cm. wide and about 1 mm. thick, bent in the middle like an umbrella rib, riveted together at the ends.

Having occasion to build a large windbreak under the shelter of which we could set up giant kites, it occurred to me that we might gain great experience in the best way of fastening our skeleton frames together, by building the structure out of large frames of similar shape. In building 799 such a structure a great saving of time and labor would be involved if it could be built up out of portable frames of similar construction as a building might be built out of bricks. As the frame of the windbreak has now been completed, it may be well to place on file here photographs showing the mode of construction and the mode of fastening the elements together.

The following is a photograph of the unit cell or skeleton tetrahedron employed in the windbreak, held by Mr. McNeal of the Laboratory.

The six sticks combined into the frame were made of spruce, 150 cm. long 3 cm. wide and 2 cm. thick. The following photograph shows a stick in three stages of manufacture, the stick nearest Mr. Ferguson is just as it came from the factory of Rhodes & Curry in Amherst; the middle 800 stick shows the next stage and the stick near the door the final stage of manufacture before being placed in the frame.

The three stages can be better appreciated in the following photograph showing one end of the sticks

801

The following photograph shows five stages in the manufacture of the corner piece required to hold the sticks together from the rough block on the left to the completed corner piece on the right perforated for the reception of a bolt and nut.

The mode of attaching the sticks to the corner piece is illustrated by the model shown in the following photograph.

802

The connecting nuts for fastening the frames together are made of solid iron, cast for me by the Atlantic Foundry (Douglas & Co.), Dartmouth, N. S. The connecting nut is a regular tetrahedron made of iron and in the center of each face a hole has been tapped with screw threads into which is screwed the end of an iron bolt; the other end of which carries an iron washer and iron nut of ordinary construction. The iron tetrahedron can thus be connected to four bolts, as shown in the left of the photograph. A single bolt with washer and ordinary nut attached appears on the right.

The model photographed in the next illustration illustrates the mode of attaching a connecting nut to a frame. The bolt passes through the wooden corner piecand the ordinary nut is screwed on pressing the washer against the 803 corner piece.

The following small model was constructed to illustrate the mode of attaching the individual frames — by means of the connecting nuts — into a solid compound structure.

804

The following illustration shows the same model held upon one edge, and at first glance it looks like an entirely different structure, but it is simply the same model shown in the last illustration held in a different position.

The above model consists of four tiers of cells.

In the next illustration — the first illustration on the next page — the lower tier has been removed leaving a structure composed of three tiers of cells held on its edge.

The second illustration on the next page shows a similar structure formed of the actual cells used in the windbreak, held in a similar position for comparison. It will be observed how admirably the structure is adapted as a support for aeroplanes, forming two large triangular wings on the outer surface, and two horizontal aeroplanes in the interior.

805 806

The wonderful strength of the windbreak structure is well illustrated in the photograph below, which consists of the same structure shown in the photograph above, held by three corners on the shoulders of three men. My daughter Elsie (Mrs. Gilbert H. Grosvenor) is standing within the structure wholly supported by it in the part that would naturally be considered the weakest portion — viz: — the center of the lower tier — and yet there is no sagging or bending of the structure perceptible. She weighs about 135 lbs.

Even with my weight in the center as shown in the second illustration below — a weight of about 245 lbs. — the sagging is quite imperceptible in the photograph.

807

The following photographs illustrate various stages in the erection of the windbreak, but the picture of the completed structure cannot yet be given on account of the illness of our photographer, Mr. George McCurdy.

A.G.B.

808 809 810

1902, Oct. 17 Friday At B. B.

Appended are three photographs of the completed framework that is as completed to date. I propose to add on horizontal sticks like the ridge pole at that part of the frame where the sail cloth is to be. The ridge pole is made of spruce 4 cm. wide and 4 cm. thick;

the horizontal sticks to be added are to be made of spruce 3 cm. wide and 2 cm. thick. The men are now at work on the pole on which the sail cloth is to be rolled, the tackel for hoisting and lowering it, and the horizontal sticks to be added to the framework.

A.G.B.

THE FOLLOWING THREE PHOTOGRAPHS WERE TAKEN BY MRS. BELL

811 812

1902, November 6 Thursday At B.B.

This dictation was taken down by Miss Sarah Marsh and has type-written ?? Miss Marian G. Graham Bell AGB

Miss Safford was called to Salt Lake City, Utah on account of the illness of her mother and left here Monday Oct. 27.

My uncle, Prof. David Charles Bell died in Washington Tuesday, Oct. 28.

Miss Safford's mother died Saturday, Nov. 1.

Daisy arrived here Tuesday evening Nov. 4, 1902.

Tracy Hubbard left here Wednesday morning Nov. 5.

The main problem I have before me just now relates to the formation of a structure having the maximum of strength with the minimum of weight.

The importance of the regular tetrahedran as an element of that structure has been amply demonstrated. The skeleton structures built up out of such elements have proved to be good solid structures perfectly braced in every direction. Indeed I hold this portion of the problem solved and do not think it worth while working any longer at the elemental form of the structure. I definately adopt the skeleton of a regular tetrahedran as the fundamental form of structure combining the maximum of strength with the minimum of weight— compound structures to be built up out of these — ad libertum as houses are built out of bricks.

The elemental form is built up of six equal rods, and I have been considering the best arrangement of length, breadth, 813 and thickness for these rods.

In a general way I have understood that the strength of a rod or stick is directly proportioned to its thickness and width and inversly proportion al ed to its length,— so that with sticks of the same cross section the shorter the stick is the stronger it is. With sticks of the same length and breadth the thicker it is the stronger, and with sticks the same length and thickness the wider it is thr stronger.

We have been examining these points quantitatively in the laboratory with very important results. The strains to which our structure will be subjected will cheifly be lateral in respsct to the length of the sticks or rods composing the structure. For example, a portion of the structure will be covered with a surface impervious to air and the pressure of the wind upon these surfaces will be — to bend the individual sticks.

We have made a series of experiments in the laboratory to ascertain the weight required to bend a stick of given length and cross section 1 cm. in the middle. The stick was supported at either end above a table so that its lower surface was 1 cm. from the surface of the table. The stick was then loaded in the middle until it sagged down sufficiently to touch the table.

We have found that with sticks of uniform length and thickness the wider sticks require to be loaded to a greater extent than the narrower, and that the load required to make them touch the table is directly proportional to the width of the stick —i.e.— double the width of your stick and you must double the load etc.

814

With sticks of uniform length and width we find that the thicker sticks require to be loaded to a greater extent than the thinner; and that the load required to make them touch the table is directly proportional to the cube of the thickness of the stick.

That is — double the thickness of your stick and you must increase the load eightfold in order to make the stick touch the table: — treble the thickness of your stick and the load must be increased twenty four seven times.

It is obvious then that thickness is of far greater importance than width. If we double the width of a stick it will weigh twice as much as it did before and be bent to the same extent by a force twice as great.

But if we turn th u i s stick edgewise edgeways(?) to the strain so that width becomes thickness the stick weighs only twice the original stick but it will take eight times the original force to bend it. Of course I always knew that it was better to present a stick edgewise to the strain rather than flatways but I had no conception until now as to how much better.

There is a certain disadvantage in presenting a stick edgewise to the surface of an aeroplane, because although it will stand the pressure of the aeroplane better in this position the stick will be presented flatways to the wind, thus offering more resistance than if presented edgewise to the wind. It has hitherto been considered desirable to arrange the framework of a kite or flying machine so that the sticks are preaented edgewise to the wind so as to lessen the head resistance as much as possible, but I am now inclined to think that the advantages gained from presenting these sticks edgewise to the 815 aeroplanes outway the disadvantages of placing them flatways to the wind. For example, let the cross section of a stick be 5 sq. cm. — say 5 cm. wide and 1 cm. thick. Now although it is true that if this stick is presented flatways to the wind it will offer five times the resistance it would do if presented edgewise, on the other hand it is also true that if presented edgewise to the aeroplane it will take twenty five times as much force to bend it as if it were presented flatways to the aeroplane.

Given a certain pressure of the wind on the aeroplane and the stick must have a certain strength in order to support it. If in order to avoid increasing head resistance we give this strength by increasing the width of the stick as presented to the aeroplane we only increase the strength five times by increasing the width five times, increasing the weight of the stick in like proportion. Instead of doing this, suppose we keep the width the same as before, we only need to increase the thickness a very little to give the same strength, so that the weight of the stick will be very much less than five times, and the head resistance also less than five times.

The increase of resistance to bending resulting from the increase of thickness is so enormous that it ts obvious to me that it will pay to arrange the framework that carries an aeroplane so that the sticks composing it shall be presented edgswise instead of flatways to the aeroplane. In other words it is more advantageous on the whole to increase the thickness rather than the width of the sticks supporting the aeroplanes.

837

1902 Nov. 15 Sat at B.B.

Chart of wind velocity at Sydney, C.B. and at Father Point, Que. During the month of October, 1902, at 8a.m.

Sydney Father Point Oct. 1 8.miles 18 miles 2 Lt. 16 3 0 12 4 0 40 5 Lt. 20 6 Lt. 12 7 Lt. 20 8 Lt. 20 9 24 10 Lt. 28 11 Lt. 12 12 0 16 13 6 10 ENE 14 6 36 15 10 16 16 Lt. 36 17 26 18 12 S 19 0 8 SW 20 36 21 8 48 22 10 20 23 Lt. 36 24 0 20 25 12 44 26 22 27 0 16 S 28 12 E 29 10 24 30 8 24 31 0 8 845

1902 Nov. 27 Thursday. At Beinn Bhreagh

My father and Mrs Melville Bell accompanied by Mr McInnis returned from Sydney Friday Evening November 14

A dance was given at the warehouse for Charles Tompson Wednesday Evening Nov. 19.

Charles Thompson left for Washington to be married Thursday morning Nov. 20.

Daisy and Sarah Marsh left for camp Thursday morning Nov. 20. accompanied by Lina McCurdy, Mr McInnis and Dan McInnis.

George McCurdy left for camp, Saturday noon Nov. 22.

Finished letter to Mr Walcott Sunday Nov. 23. and prepared telegrams to Mr Walcott and Pres. Gilman same evening.

Daisy, Sarah and George McCurdy returned from camp Monday Nov. 24.

Telegrams to Mr Walcott and Pres. Gilman sent Monday Nov. 24, and same day Mabel made type-written copy of my letter to Mr. Walcott, as the original had been romewhat blurred in press-copying.

Tuesday Nov. 25, Mabel's birthday, and our engagement day. My letter to Mr Walcott, and Mabel's type-written copy mailed early in the mrning. Telegram of congratulation from Tamworth Ont. to Mabel says “44 kisses from Hattie and Arthur none.”.

For a long time past the Lab. Annex has been filled with large kites waiting to be tried, but there has been hardly any wind.

The investigation concerning wind velocity at Syndey and Father Point (this vol. pp 832 to 844.) shows that is til it is not much use waiting for wind,) shows that it is not much use waiting for wind, for it seems that at Sydney the wind does not reach a velocity of ten miles an hour more than about 17 days out of 100. The wind vel. here cannot be materially different from that at Syney. The Weather Bureau reports are made at 8 A.M., whereas our experiments are made in the afternoon, but this shd not materially effect the results, for as a general rule the wind here is stronger in the forenoon than in the afternoon, usually dying away in the 846 midst of our Kite exp.

Sunday Nov. 16. Mabel suggested flying kites by attaching them to a galloping horse, and on Monday I timed our horse McKinley while he ran with a small kite. Mr McKinnon rode the horse, and held the string of the kite in h e i s hand. The kite flew well, and over the short distance measured, the vel. of the horse was 19 miles an hour going at his fastest gallop. This showed me that we can always be sure of the equivalent of a wind exceeding 10 miles an hour, by raising the kite by means of a horse., and it therefore seemed worth while to train d a horse for this work, so that he shd not be frightened by the pull of our large kite s .

On Tuesday Nov. 18 we harnessed up the horse McKinley to one of our large kites. The result was a great success. The kite flew well and the horse did not seem to mind the unusual strain to any great extent. Mr McKinnon rode the horse, and the manilla rope attacted to the kite was passed through a t m e tal ring on the collar of the horse, the end being held in Mr McKinnon's hand, so that he cd let the kite go in case of an emergency. We established a set of fog-horn signals for “Stop”, “Go ahead”, and “Let go the line!” These seemed to work well.

On Tuesday Nov. 18 was a slight breath of air, and the hope horse was started against the wind, the large kite attached rose very gracefully. Two blasts on the horn brought the horse to a stand still, but it was found that the wind was just not enough to sustain the line , kite which began to fall slowly. Three blasts on the horn started the horse up again, and when the kite had ascended attained to its highest elevation, a rapid succession of short blasts signalled Mr McKinnon to let go the line without stopping the horse . The kite then began to fall, and finally landed on the grass.

Although we have had very little wind since the 18th inst. our experiments have not been interrupted for one moment on this account. We have had all our larger kites up, and have been able to study their mode of flight in the air, and their mode of descent when released. These are some disadvantages however about this mode of flying kites, which may however be remedied in the future.

The motion s of the horse in galloping gives an intermittent 848 pull to the rope — and the motion of the horse is reproduced in the kite. The kite gallops as well as the horse. This is especially true of the lighter kites in the absence of wind. Both wind and weight seem to steady them. It is probable that the horse will exert a more steady pull if made to trot instead of to gallop.

The other disadvantage is that in flying kites without wind we are obliged to let them fall on the ground, and cannot save them from the e? effects of contac t. The larger kites are (absolutely) heavy, so that however gently and slowly they descend if they strike the ground at one point the strain on that point is severe. As a matter of fact we nearly always smash some sticks in alighting on the ground.

Our kites fly with stern somewhat depressed, and when released they have way instead of head-way under the action of the wind, so that the stern has a tendency to dig into the ground, and that is the cause of the damage done. We have not hitherto had to give much attention to this matter, because in a wind sufficient to support t hekite — we can almo s t always bring it safely down without even touching the ground. Even when we allow ed the kite to fall on the ground we avoid injury by giving the kite head-way at the moment of contact by pulling on the cord or rope. The stern then has no tendency to dig into the ground. The g round— in effect — strikes the kite a glancing blow — the stern scrapes along the ground while the bow comes down. Skill is required to give the necessary head-way just at the right moment. We have acquired that skill here, and we can nearly always bring down a kite safely in a wind that i t s capable of supporting it.

Perhaps it is just as well that our attention is directed to the problem of landing without destructive shock when the machine is left to itself.

In the case of kites — and of flying-machines that have lost their propelling power through some accident to their machinery — the machine will drift with the wind in coming down — that is — they it will have stern-way. In order therefore to reduce the shock at lighting it is very advisable that the stern shd not be depressed at the moment of contact with the ground — I it wd better that the bow shd be depressed so that a glancing blow shd be struck. (Ofcourse 849 if the machine had head-way the case wd be entirely different, it then being more advisable to have the stern depressed.)

I tried the experiment of hanging an anchor from the bow of a kite by a linetwo or three times longer than the kite itself

I expected that when the kite was released the anchor would catch in the ground or at all events retard the drift of the kite — before the kite reached the ground thus pulling down the bow of the kite at the critical moment, so that the kite would land upon an even keel, or with its bow depressed.

I reckoned however without considering the effect of the weight of the anchor, and as a matter of fact it acted in the very opposite way to that intended. The moment the anchor touched the ground the bow of the kite being relieved of the weight arose in the air thus depressing the stern which was smashed by contact with the ground. The anchor also interfered with the proper flight of the kite in the air. By its weight it brought the centre of gravity too far forward, so that the kite did not fly at as high an angle of cord as it would have done without it; and the swinging of the dangling weight caused the kite itself to move about unsteadily in the air.

A.G.B. per M.G.B.

850

1902. Nov. 28 Friday. At Beinn Bhreagh.

There are a whole host of exp. and thoughts that have not been recorded here — and probably never will be now. Will try to save a few or at least put down a few words that may recall ideas later on.

Automatic weather stations, and at regular intervals of height on kite wires Home Notes, Nov. 3. p. 95.

Nov. 3. Sent note to Weather Bureau, as follows; “Prof. Willis Moore Weather Bureau, Washington D.C. Mr dGraham Bell wishes to suggest to you that kites might be elevated from moving railroad trains in many parts of the U.S. — daily — at 8 A.M. and at 8 P.M. — to take observation of weather conditions at a certain height in the free air for comparison with surface observations.” This was signed by Sarah Marsh Sec. pro tem. I have since heard from Prof. Willis Moore and I find that this very obvious idea is new to all the officers of the Weather Bureau, and is not either to be has not been considered at all.

It seems to be universally considered that an aero-curve is more effacious than an areo-plane, but I do not know that any sufficient cause has been assigned.

Comparing the aero-curve to the upper part of the human mouth — an eddy wd be formed behind the gum of the aero-curve. The partial vacuum existing there wd cause the passing air currents to be deflected upwards so as to strike the palate of the aero-curve at a greater angle than if the gum were not there — thus creating a greater lift. (Home notes Nov. 4 p, 100)

The power of rubber diaphragm in compressed air toy proposed to be utilized in various waysthrough an arrangement like a pair of parallel rulers (Home Notes nov. 13 and 14 pp, 117 to 120). These plans worked 851 so successlully in Lab. that parallel ruler arrangements will probably be adopted in practical toys. I have been very anxious to find some practical way of making small skelton tetrahedrons of wire for the purpose of studying the charecter of the structures resulting from their combination in various ways, but had been met by the difficulty of fastening them together in some sim p le way. On Monday Nov. 17 Mabel suggested sealing— wax. (See Home Notes Nov. 18 p. 165) At first sight this seemed to be impracted cable on account of the brittleness; but when i reflected that glass was very brittle in thin sheets and yet that boy's glass marbles wd stand a great deal of rough usage without breaking — it seemed worth while trying. This has been done with great success

Mabel has made a number of small tetrahedrons of hair-pins stuck together with little balls of sealing— wax. These seem to be very strong and stand handling well. By heating the balls gently over a flame the tetrahedrons are easily joined together into a compound structure, and the compound structure itself is so strong as to bear handling well. Mabel has made a compound tetrahedron of four tetrahedrons as follows:

She has also combined four of these compound tetrahedrons into a still larger structure constituting itself the skelton of a tetrahedron. The following is a side elevation of this

All these structures proved to be strong and handlable.

A.G.B. per M.G.B.

852

1902. Nov. 29. Saturday. At Beinn Bhreagh.

Idea. three dimension weaving developed Home NotesNov. 17. pp 139 to 144 “Important practical thought — <u>thread wire into rings.</u> .

Just as now we weave threads (or wires) to form a surface (cloth calico &c wire-netting — mosquitoe netting &c) so it shd be possible to weave wire to form a <u>solid</u> structure in three dimensional space — a skelton solid — <u>a three dimensional cloth</u> or wire netting.

First weave a wire netting with triangular cells — forming a flat surface —. Then weave these surfaces together — through the rings

With rings this wd really be sewing not weaving

Why not weave leaving triangular holes through which may pass the wires to connect different layers.” &c.

“The principle of walking toy mght be applied to new methods of man Propulsion on the ground. Let Man take the place of a rubber diaphram — walking-chair. Walking boat — mght be on wheels.” The above ill. by drawings, see m Home Notes for Nov. 19 p 148.

Another variation of the same idea on p. 152in the form of a stepping machine for moving on ungraded ground may even be arranged to step over obstacles.” — “He practically walks on stilts. Multiplies his steps — makes steps (say) ten ft long. His Centre of gravity may be low as in case p. 148 and still get increased step.” (p 152.) “This thing walks like a paralyzed man. Advances one leg and d rags the other after.” p 158.

The idea of a Govt Bureau of Research on the model of the Patent Office developed Home Notes Nov. 25 pp 167 to 170.

An open pipe of great length can be made to fly as a kite but it lacks one essential element of stability — the power to keep itself approximately horizontal in the air. If allowed to fall

One end or the other turns down and it dives to the ground

853

This diving tendency can be iliminated by cutting out the centre part of the pipe leaving the frame work alone there, thus converting the pipe into a two celled kite. The greater the space bet. the two cell the more certainly does the k ite keep its horizontal position in falling.

This mode of securing fore and aft stability by two cells well seperated from one another is well known and has been especially developed by Hargrave if indeed it was not original with him. One cell fore and one cell aft with a large space bet. secures freedom from pitching motion.

Why shd not same principle be employed to secure freedom from rolling? Let there be a cell on either side and none bet.

The importance of avoiding aero-plane surfaces, in the middle grows upon me as a principle of stability inthe air. If you want to stand firmly on the ground, spread your legs wide apart, and if you cd only have a third leg, you cd convert yourself into a tripod stand, which position wd be still more stable. Your centre of gravity must be well within the ba ? s e of support. The wider the legs can be spread the better, or in other words — with they a base of given extent, the lower the centre of gravity.

now have we got here the conditions of stability in the air up side down We need at least three aero-surface points of support, like the three legs of the tripod. These want to be seperated far away from one another. The centre of gravity shd be underneath the centre of the triangle connecting them, but as close up to the plane of the triangle connecting them as practicable

I see this ideal arrangement in a bird, the centres of air pressure in the two wings and the tail, constituting the three points of support well seperatid from one another. The weight of the bird comes in between 854 and so slightly below the plane of the triangle that this plane can be tipped very considerable in any direction, without bringing the centre of gravity outside the ? base ? of support. This seems to me to be the principle of stability in the air.

While theoritically the centre of gravity shd be under the centre of support still numerous disturbing conditions exist in the air, it is important therefore to have an extended base of support, and the centre of gravity so nearly in the plane of support that it cannot get outside the base even when that plane is far from the horizontal. Under these circumstances there will be a tendency to a recover i y ? of the horizintal position, so long as the centre of gravity is within the base.

there is an important principle here — though not well expressed With atripod ? s tand only three points of support exist, it is not necessary that the space in between shd be filled in solid. And so in the air it is necessary that there shd be at least three centres of support well seperated from one another, but it is not necessary — nor perhaps advisable to have supporting surfaces between. This is the special point that strikes me. That the parts immediately above the centre of gravity need have no supporting surfaces — and indeed taat it wd be better to avoid supporting surfaces there . F or dewelopement of this idea Home Notes Nov. 27 and 28 pp 173 to 175.

A, G. B. per M. GaB.

855

1902. Dec. 1. Monday. At Beinn Bhreagh.

A kite being anchored to the ground, is stationary in the air — and has no momentum proper of its own. It therefore derives all its support from the resistance of the air.

The moment however we convert the kite into a flying machine by giving it a means of propulsion we give it another means of support. — Its own momentum. If we drive machine, mdash; say at a rate of ten miles an hour, the effect undoubtedly will be the same as though the machine were at rest and the wind blowing ten miles an hour, SO FAR AS AIR RESISTANCE IS CONCERNED. This resistance is the equivalent of the momentum of the air — not the machine — the moving and with the given velocity. The momentum of the machine may be very different. In a body e specifically lighter than the air (like a balloon) the momentum at any given velocity wd be less than the momentum of air at that velocity — so that shd the balloon be driven by the action of propellers against a head wind, the balloon wd drift with the wind the moment the propellers stopped.

On the other hand , in a machine e specifically heavier than the air the momentum of the machine at any given velocity is greater than the momentum of its own bulk of air, at that velocity. Hence if such a machine be driven against a head wind the machine will not stop when its propellers cease to act, but will go on moving against the wind, by virtue of its own superior momentum, with diminishing velocity on account of the resistance of the air, until it comes to rest. Then, and not until l then, will it begin to drift with the wind.

I cannot over rate the importance of the point that the momentum of the machine is a different thing from the momentum of the air, and that the 856 excess-momentum over and above the momentum of an equal bulk of air moving at the same velocity — IS A SOURCE OF SUPPORT, independent of, and additional to, that derived from the resistance of the air.

I know of no better name for this source of support than PROJECTILE FORCE.

It is the same force that supports projectiles in their flight — a stone from the hand , an arro u w from a bow, a bullet from a rifle, owe their support to the excess-momentum they posses over the momentum of an equal bulk of airmoving at the same velocity. This portion of their momentum — which I term their projectile force — is hindered not helped, by the resistance of the air. The stone the arrow, the rifle bullet, wd travel further and go higher against the action of gravitation in a vacuum than in the air.

Machines that are specifically heavier than the air — when they move under the action of suitable propellers — all possess projectile force to a greater or less extent, depending upon their specific gravity. The greater the specific gravity , the greater the projectile force, contained in their movements.

As the resistance of the air opposes and retards motion due to projectile force , wings or aero-planes or other instrumentalities for gaining support from the resistance of the air, have this the disadvantage of interfering with support due to the projectile force itself, — by retarding velocity. The greater the specific gravity of the machine, the less does it need supporting surfaces, (like aero—planes &c.) up to the extreme case of the rifle bullet, which flies very well without utilizing 857 the resistance of the air at all. And we cannot doubt that a rifle bullet wd neither fly so far or nor so well if provided with wings as it does without.

Bodies that are specifically lighter than air are supported in the air while at rest ; and if moved against the air possess no excess momentum — or projectile force. On the contrary they have a sort of minus projectile force — that is — the air possesses projectile force over them. They can only move under the direct action of their propellers or under the ac t ion of the wind.

Bodies that are specifically heavier than the air are not supported in the air when at rest, but when in motion they can gain support in two ways:

1. By utilizing the resistance of the air, through the action of extended surfaces, and

2. By utilizing their projectile force.

The greater the projectile force the less necessary are extended surfaces.

The projectile force depends primarily on the specific gravity of the machine as a whole and secondarily upon the velocity.

Where the specific gravity of the machine is equal to — or less than that of the air — it can possess no projectile force, whether at — at rest, or in motion.

Where the specific gravity of the machine is greater than that— of the air, it possesses no projectile force when at rest—, but it does possess projectile force the moment it moves.

860

1902. Dec. 2. Tuesday. At Beinn Bhreagh

The following photos. ill. an attempt made on Nov. 19 to fly one of our larger kites without wind in the manner described on pp. 845–849. by attaching it to a galloping horse

fig 17

This is a photo. of the kite employed.

And this is the horse, harnessed to the kite, ready to start.

The kite is too far to the left of the picture to be seen. The connecting rope also does not show as it is lying on the road.

861

fig 18

The above photo. ill. the process of raising the kite by a horse. Both the horse and the kite are blurred because both were moving when thh photo. was taken. For the same reason the connecting rope does not show. The photo. was taken very soon after the horse started, and shows the kite just rising up into the air. The following photo shows the kite at its highest point of elevation

fig 19

As there was only a breath of wind, not sufficient to support the kite, the kite came down when the horse stopped or the rope was released.

ABG

862

1902. Dec. 3. Wednesday At Beinn Bhreagh.

In looking over my notes of Monday Dec.1. pp. 855 & 859 relating to projectile force, I am a little uncertain whether the specific gravity of the machine is really the primary point connected with projectile force.

Specific gravity is a different thing entirely from what I have been in the habit of calling "flying weight" — "or ratio of weight to surface".

Specific gravity is the weight of the body compared with the weight of its an equal bulk or volume of some other body (Distilled water at a certain temperature and barometric pressure usually being the unit of comparison).

Flying-weight, or ratio of weight to surface is the weight of the body compared to its surface (1 Sq. metre being considered the unit of surface).

I am a little uncertain at the present moment whether the primary constituent of projectile force is great specific gravity, or great flying-weight. This requires more consideration and thought, for it is a matter of great importance.

We shd distinguish carefully between there two kinds of relative weight, and I am inclined to think that in aero-dynamical researches it wd be better to translate specific gravity to mean the weight of the machine as compared with an equal bulk or volume of air at standard temperature and pressure; and to translate flying-weight to mean the weight of the body upon each square metre of horizontal surface. It wd also be better to coin a new word to express what I mean by "flying-weight". All authorities agree in recognizing the importance of ascertaining the ratio of weight to horizontal surface, or as it is 863 often termed “Supporting— surface.” but no name as been assigned to this kind of relative weight.

I have used “flying-weight” to express the relation of total weight to total surface, irrespective of the inclination of the surface. Horizontal surface alone does not express the important point we wish to ascertain, — namely the amount of surface concerned in the support of the body in the air. It is obvious that a vertical surface does not support at all — only horizontal surfaces support. An oblique surface shd therefore be resolved into equivalent horizontal and vertical elements. The horizontal constituent alone being considered as supporting surface.

But horizontality alone is not sufficient for support, for if two horizontal surfaces be laid close together one above the other, the upper one obviously does not support at all. ? A certain space is necessary bet. superposed aero-planes, in order that each shd act independently of the other in supporting the body in the air. It is a little difficult to decide what does and does not constitute that important element “Supporting” surface.

On the whole I am inclined to think that it wd be well to ascertain the extent of horizontal surface exposed below. Project all the surfaces on to a horizontal plane below, and consider the a rea of this plane covered as an indisputable area of supporting surface. In other words, Look up at the machine from a point directly below and all the surfaces that can be seen — considered as projected on a horizontal plane, are indisputably supporting surfaces. This wd give us an estimate of minimum supporting surface. Other surfaces, above what can be seen may or may not, contribute to the support of a machine falling in still air. It wd be 864 safest, I think, to consider that under such circumstances they do not support at all. If these super-posed surfaces are sufficiently seperated from one another they certainly do aid in the support when the machine has head-way or when the wind is blowing, but how far the wd support without aero-planes head-away in a dead calm, is to say the least problematical.

We must provide for the case of a machine whose machinery has broken down so that it in loses all head-way, and as this may happen in a calmit is important that it the machine shd be provided with sufficient supporting surface to cause it to come down slowly and gently to the ground or wate r .

It wd be well then to ascertain in every case the minimum supporting surface — the total amount of surface as projected upon a horizontal plane below.

A. G. B. per M.G.B.

This “ basal projection ” I am inclined to think of fundamental importance.

AGB Feb 5 1902

865

1902. Dec. 4. Thursday. At Beinn Bhreagh.

In our exp. relating to the resistance to bending possessed by spruce sticks of varying length, breadth and thickness pp. 819–831. the sticks were placed loosely upon two supports, and exp. were made to ascertain the load required to bend them down one Cente metre centimeter in the middle.

A See p. 819

B See p. 821

The In the actual construction of kite frames the sticks are not loose at the points of support, but are there rivetted and glued together.

I made a series of exp. at the Lab. to ascertain whether attachment to the support affected the general conclusions reached regarding length.

A stick of spruce was taken 100 cm. long 1 /cm wide and 5 mm thick. this was tacked on to two supports 1 cm thick and (one at either end) and the supports were themselves tacked on to the table. An adjustable support 1 cm thick was then placed under the stick between the other supports at various places — The stick being tacked to th is support s & the support s to the table before each observation

C &c &c.

866

The results noted were as follows:

Length between supports Loud required to bend stick 1 can in middle Proportionate lengths Proportionate louds on basis of one million 1 1 000 000 2 202 417 30 cm 3310 gms 3 77 039 40 cm 1750 gms 4 40 730 50 cm 960 gms 5 22 344 60 cm 670 gms 6 15 594 70 cm 450 gms 7 10 474 80 cm 375 gms 8 8 728 90 cm 255 gms 9 5 935

The following Table enables us to compare the results obtained in the three sets of observations; — A. Sticks loose upon supports, and not protruding beyond (see p. p. 824) — B Sticks loose upon supports and protruding beyond them, (see p. 825)— C. Sticks tacked to their supports (see results noted above.)

Proportionate lengths Proportionate Louds on basis of [???] million A B C See p. 824 See B. 825 See above 1 1 000 000 1 000 000 1 000 000 2 94 189 121 154 202 417 3 24 060 35 493 77 039 4 8 872 14 678 40 730 5 4 436 7 442 22 344 6 2 266 4 300 15 594 7 1 520 2 605 10 474 8 836 1 778 8 728 9 579 1 260 5 935 867

These results are shown graphically in the following diagram in comparison with Curves representing a series of numbers inversely proportioned to the squares , (Cubes) , and Fourth Powers of the proportional lengths — the wh ole on a basis of One thousand: —

868

While the sticks support a greater load when fastened to a support than when loosely resting on them, the rate of increased resistance to bending as the length bet. supports is reduced — is not so great as when the sticks are free.

A., when the sticks rest loosely upon the supports and do not protrude beyond, the resistance to bending 1 cm in the middle isinversely proportioned to the length of the stick — the loads required varying inversely as the cube of the length or at some greater rate (the actual curve coming somewhere about half-way bet. the curve of inverse cubes and the curve of inverse 4th Powers)

B., when the sticks rest loosely upon their supports with the ends protruding beyond, the load s required to bend them 1 cm in the middle is inversely proportioned to the length — the load varying inversely as the cube of the length, or at some greater rate. (the actual curve differs very slightly from the curve of the inverse cubes).

C., when the sticks are tacked to their supports the load required to bend them 1 cm in the middle is inversely proportioned to their length.— the load varying inversely at some greater rate than the square of the length. (the actual curve comes about mid-way bet the curve of inverse squares, and the curve of inverse cubes).

GENERAL RESULTS—

If the ends of a stick protrude beyond the points of support, this in a measure fixes the pointsof support, and so as though they were partially attached and the greater the extent of protrusion the greater the attachment to the supports. I therefore look upon the A B C series of exp. as showing three different grades in the firmness of attachment, and at the 869 points of support. The sticks are more firmly attached in the B Series than in the A Series, and more firmly in the C Series than in the B Series. This progressive increase in the firmness of attachment has been accompanied by a progressive diminution in the rate of increased resistance to bending as the sticks are shortened — so that it is probably that if the sticks were still more firmly attached to their supports by being screwed and glued there the rate of increase wd be still less, and more nearly proportioned inversely to the square of the length than the cube (the curve wd probably approxima n te still more closely to the curve of inverse squares, than in the case of the C Series of exp.). A.G. B. per M.G.B.

870

1902. $ec. 5. Fri. At B. B. Note by Mrs. A. G. B.

Been thinking a good deal about ways of launching flying machine. Propose to use House-boat seat for exp. station. House for storeing flying-machine will be up the gu l ly on the other side of the pond, some distance back where the land is quite steep, so that the house will be quite high up, and yet beside the little straem that makes the pond. From the house wooden troughs may be constructed that would carry water down across the pond into the lake. Into these troughs the keel of the boat of the fling-machine would fit.. When the machine is ready for launching, water would be turned on into the t s r oughs, the keel of the machine floated on it, and thus carried with a rush down towards the lake with such momentum that its propellers should be a able to glide the boat right over the surface of the lake, and up into the air. Quite independently of flying-machines, this method of starting a boat shaped machine would be quite feasible for gliding-machines. The machine coming down with the great force would glide over the water and in the air for quite a long distance, and afford a new sport for people analogous to tobagganing.. There might be money in it. Mr Totten of Washington has talked with me about it a similar idea similarities quite often, but he contempated starting his machine with wheels. (?) The use of a water trough in which a keel shd and float is new with me just now.

(This is the substance of a conversation recently had with A.G.B.) M.G.B.

871

1902. Dec. 6. Saturday. At Beinn Bhreagh

Mr Graham Bell is very tired this morning. Will try to note some things that he has spoken of.

Home Notes pp. 182–186 and 195–196 (Earlier Safe.176 only) show the evolution of the idea that aero-planes themselves could be made to do duty also as framework, thus obviating, to a great extent, at least the necessity of an elaborate frame work.. Monday De.1 The note records; “Four skeleton tetrahedrons covered with silk”........” were arranged as larger tetrahedron and tried as kite from bamboo pole this evening about dusk. Hardly any wind — but kite flew well at great angle to pole.

Weight 195 gms

Surface 1.1 &c (?) sq.M.

Flying-weight 174 gms per sq.M. My recollection only.”

Following diagram copied from same p. of Home Notes.

Home notes continue; “If verified by exp. tomorrow — this means — a cellular construction without any other frame-work than the aeroplanes themselves. The flying — weight of compound kite being the same as that of component kites. All we have to do is to select 872 a surface material whose ratio of weight to surface comes within our limits of flying-weight. (For Cape Breton Island 400 gms per sq.M..) For example take aluminum alloy in thin sheets having a less weight than 400 gms per sq. M. of surfamce. Cut from it a diamond shaped piece bend along dotted line also cut a slip for a narrow horizontal aero-plane. Insert and rivet

If material seems too thin — reduce size of the cell — until requisite stiffness obtained.

Then build up large compound structure out of these cells — and the large structures will have the solidity of the small cells — indeed greater solidity — for all the cells co-operate and divide strains among them.

Head resistance reduced to a minimum weight and resistance of special frame also avoided. Rivet cells together. Pinch the ends of the keel together to form a good riveting place for attachment to neighboring cells. ”.......... “If cells are made small enough the whole thing may be made of metal — (aluminum alloy or steel).. The metal surfaces with holes for riveting can be punched out of a sheet of aluminum alloy or steel.”

On next page I will make a copy of drawing shown on p. 183 of Home Notes.

873

I think is was the next morning, Tuesday, Dec. 2, though it may have been Sunday Nov. 30,* that Mr Graham Bell made some little diamond shaped things of paper, and asked me to put them together as tetrahedrons with matches. We tried first to do it by attaching the matches to the inside points of the pieces of paper with sealing— wax. This was not satisfactory, and the exp. was adjourned for that day. This makes me think that this first trial was Sunday, and that it was on Tuesday that I succeeded in making a satisfactory model by making holes through the points of the paper through which I pushed the ends of the matches, holding them firmly there by means of sealing— wax. This made one tetrahedron cell, the cells were then fastened together with sealing

* Yes — Sunday. On Saturday night Nov. 24 p.176 “Try a model of paste-board-matches and sealing wax“ This was done day. AGB

The paper diamond were probably cut out Sat. night Nov. 29 — it is possible first attempt to write them was made seem — but I think Sunday. AGB

874 wax, and formed into four celled tetrahedrons like that drawn on p 873. (As I come to think over the matter however as an historical fact I am certain that I have fixed the date of this exp. several days too late. George McCurdy left Dec. 1, Monday,* and he had seen the paper an and match model, and it was after doing this, and before he went that I tried to get an idea of the construction of his log cabin by putting matches together. The

completion of the model of which the accompanying sktch is a drawing, must therefore have ante-dated Mr Graham Bell's exp. of Monday afternoon. Yes. AGB .)

* No. He took at Judge that evening. See Home Notes p. 182. he and # M cCurdy left Wed. morning Dec. 3 — If not this — Thursday — but I think Wednesday. AGB

875

1902. Dec. 9. Tuesday. At Meinn Bhreagh. Dictation by A.G.B.

I have found it important to ascertain the normal pressure of the wind upon a surface at right angles to it, but have been able to find but very little information upon this point in books relating to aero-dynamics. It seems to be assumed that the wind pressure under such circumstances varies acc. to the sq. of the vel. and this tallies with my recoll. of my own exp. What — fail ed to find in is a statement of what pressure corresponds in what vel.. In Davis' Elementary Meteorology a table is given on p. 94, from wh. I find that a wind vel. of 5 M. per sec. exerts a press. of 3.15 kg per sq. M. of surface opposed to it: and the table is evidently constructed upon the theory that the press. varies as the sq. of the vel.. Using Eavis' fig. as a basis, I have constructed a table wind press. wh appears in this vol. p 7911..

In 1893 the U. S. weather Bureau pub. a Cir. of Information upon Anemometry prepared by Prf. Marvin. From this pamp. it appears that the wind press actually experienced at dif. wind vel. are materially less than those usually assigned in text books &c. this led Prof. Marvin to construct a table of Wind Pressures from actual obs. and the results are given at p. 10 of the Weather Bureau Pub.. Another useful Table appears in the same pampf. p. 39 enabling the obs. to estimate approx. the vel. of the wind by its effect upon inanimate objects (smoke, leaves of trees, white caps on water, &c.,) I copy these tables here for reference, (See pp 878, 879.)

For my own use it is advisable to convert miles per hour into metres per second ; and pounds per sq. ft. into grammes per sq. metre. My daughter Marian has made the necessary cal. and has prepared the 876 following Table based upon Marvin's fig.

Marvin.

Vel in miles per hour Press. in lbs per sq. foot. Vel in Metre per second Pressure in grammes per sq. M. 5 .104 2.5 507.2 10 .369 5.0 1803.4 15 .762 7.5 3724.1 20 1.27 10.0 6206.8 25 1.90 12.5 9285.8 30 2.64 15.0 12902.4

These results are shown grahpically in the fol. diagram in comparison with Davis' results and a curve of sqs. showeng what the wind press. wd have been at any given vel. if the increase of press. had been strictly proportional to the sq. of the vel. upon the assumed basis of 100 gms per sq. M for a wind vel. of 1 M. per sec.

A.G.B. per M.G.B.

877

WIND VELOCITIES and Pressures

878

1902. Dec. 10. Wednesday. At Beinn Bhreagh.

TABLE OF WIND PRESSURES. (POUNDS PER SQUARE FEET.)

Indicated Velocity In miles per hour. +0 +1 +2 +3 +4 +5 +6 +7 +8 +9
0 .104 .144 .190 .243 .303 10 .369 .433 .511 .586 .666 .762 .853 .949 1.05 1.16 20 1.27 1.38 1.50 1.63 1.76 1.90 2.04 2.19 2.34 2.48 30 2.64 2.81 2.98 3.14 3.32 3.50 3.67 3.87 4.04 4.24 40 4.44 4.64 4.84 5.07 5.27 5.51 5.72 5.93 6.18 6.40 50 6.66 6.89 7.12 7.40 7.64 7.88 8.14 8.43 8.69 8.95 60 9.22 9.49 9.76 10.1 10.4 10.6 10.9 11.2 11.6 11.9 70 12.2 12.5 12.8 13.1 13.5 13.8 14.1 14.4 14.8 15.1 80 15.5 15.8 16.2 16.5 16.9 17.3 17.6 18.0 18.4 18.8 90 19.2

From “Anemometry” — a circular of Information prepared by. C.F.Marvin, and issued by the Weather Bureau 1893, — p. 10.

879

ESTIMATED VELOCITY OF WIND.

NAME MILES per hour APPARENT EFFECT. Calm 0 No visible horizontal motion to inanimate matter. Light 1 to 2 Causes smoke to move from the vertical. Gentle 3 to 5 Moves leaves of trees Fresh 6 to 14 Moves small branches of trees and blows up dust Brisk 15 to 24 Good sailing breeze and makes white caps. High 25 to 39 Sways trees and breaks small branches. Gale 40 to 59 Dangerous for sailing vessels Storm 60 to 79 Prostrates exposed trees and frail houses. Hurricane 80 or more Prostrates everything.

From “Anemometry” a Circular of Information prepared by C. F. Marvin, and issued by the Wheather Bureau. 1893. p.39.

880

A COUP D'OEIL.

I do not remember what first caused me to take up the serious study of kite structures. i have now been at work upon this subject for some years — why — I dont know — excepting that I can help it. The whole subject has a fascination for me largely , I think, from its bearing upon the flying-machine problem. I have always been interested in this problem as far back as I can remember. I think that my persistence in kite exp. arises from the feeling that a properly constructed flying-machine shd be capable of being flown as a kite; and that therefore — conversely a suitably constructed kite shd be capable of being flown as a flying-machine when driven under by its own propellers.

The applicability of kite exp. to the flying-mach. problem has at all events — for a long time past — been my guiding idea. I have not cared to ascertain how high a kite may be flown — or to make one that shd fly at a great altitude in the air, excepting that i have recognized that a kite that will fly almost vertically overhead is better adapted for flying-machine s u tructure, than one that flies very little above the horizon — the latter structure being more suitable, however, for the purpose of towing boats.

Great lift and little drift is what is wanted for a flying-machine. Little lift and great drift is what is wanted for towing boats.

A structure suitable for a flying machine shd fly at a considerable angle to the horizon, and directly with the wind.

kite suitable for towing boats shd fly at a low angle and off the wind, and we shd be able to control the deviation of the kite from the true direction of the wind, so as to make it fly alternateley on either side of the wind as desired, and at as great as angle with the wind as possible up to 90° from the wind, because the possibility of controlling the deviation so as to make the kite fly alternately from to one side to or the other of the renders it possible to tack against the wind as with an ordinary sail-boat.

Thus the anti- thetical structures are both useful, and the elements that affect the vertical and horizontal angles of flight shd be carefully studied. Those features that are inadvisable in a flying mach. may be very advantageous in a boat-towing devise, and vice versa. A structure constitutes a good kite or a poor one acc. to the use intended What wd ordioarily be termed a poor kite — that is — one that flies at a low angle to the horizon and to one side of the wind is just what is wanted for boat-towing purposes, provided the deviation from the 881 true direction of the wind can be controlled, so as to make the kite fly alternately to one side or the other of the wind.

For both purposes however the equilibrium of the structure in the air shd be perfect — it shd fly steadily and not move about like an imprisoned bear; an d it shd possess grt strength so as in the one case — to carry a grt load, — and — in the other case to stand a grt pull. For both purposes also the kite shd be adapted to flt on water so that — in the one case — it may come down with its living load without dangar to life or limb, and — in the other case it may light without injury to itself and be recovered.

The points that I have had specially in mid have been — Strength, Lightness, and Steady Flight.

I believe that in the form of structure now attained these three problems have been successfully solved.

In my younger days the word Kite suggested a structure of wood in the form of a cross covered with paper, making a diamond shaped surface, longer one wa y than the other, provided with a long tail, composed of a string with numerous pieces of paper tied at intervals upon it and flown by a brid d le 882 Such a kite is only a toy and in Europe and in america, where kites of this type prevailed, kite flying was pursued only as an amusement for children and the improvement of the form of structure was hardly conceived as to be a subject of thought suitable for a scientific man.

In Asia however kite-flying was the amusement of adults, and the Chinese, Japanese and Malays developed tail-less kites very much superior in every way to the forms of kite employed by more civilized nations. As kite-flying however was supposed to be a sub j ect unworthy the attention of scientific men the kites used by Asiatics were little known in Europe or America, and were not made the starting point for fresh delelopements.

It is only comparatively recently within quite recent times that improv. in kite structure have been seriously considered.

The recent delelopements in this art have been mainly due to one man, Hargrave of Australia. He foresaw that the structure best adapted for what is called a good kite wd also be suitable as the basis for the structure of a flying-machine. His scientific researches — pub. in Australia — have attracted the attention of the world — and form the starting point for modern researches upon the subject in Europe and America. Anything relating to Aerial locomotion has an interest to many minds and scientific kite-flying has been stimulated every where by Hargrave's exp.. War kites are being del. developed by the War and Naval Depts of different nations and the Russian left is now equipped with man-lifting kites, capable of lifting a man to a grt elevation in the air when towed by war vessels — for purposes of obsv.

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In our own country the fact was devel. by our Weather Bureau that important information cd be obtained concerning weather conditions if kites cd be. constructed capable of lifting metereological ins. to a grt elevation in the free air. This object has been the main stimulous to scientific kite flying in America, and grt improv. have been made by Eddy — basis upon the Malay tail-less kite, and by Prof. Marvin of the Weather Bureau, and Dr Ress Botch of the Blue Hill Obs. — basis bas ed upon Hargraves exp. Congress made a direct approp. to the Weather Bureau in aid of its kite exp., and a number of Meteorological stations were equipped with the Marvin kite. Dr. Ress Botch has demonstrated the poss. of taking continuous Meteorological obs.at.a.grt elev. all the way across the Altlantic by means of kites towed by trans-Atlantic steamships.

In spite of the numerous exp. undertaken by these and other capable men I think it safe to say that no material impr. in kite structure have yet been made over Hargrave's apparatus — unless indeed it has been done at Beinn Bhreagh.

Hargrave introduced what is known as the cellular construction of kites. He constructed kites composed of many cells, but found no substantial improv. in many cells over two alone, and a kite composed of two rectangular cells separated on a considerable space is now universally known as “the Hargrave Kite”. This represents in my opinion the high-water mark of progress in the nineteenth century and this form of kite forms the starting point for my own researches. The two cells were in are on the same horizontal level one constituting the front of the kite the other the rear. They were are connected together 884 by a frame-work consisting of one or more longitudinal sticks so that a considerable space was is left bet. the fore and aft cells. This space is the most essential feature of the kite. Upon it depends the fore and aft stability of the kite. The greater the space the more stable is the equilibrium of the kite in a fore and aft direction — the more it tends to assume a horizontal position, and the less it tends to dive or pitch.

Each cell is provided with vertical sides these again seem to be essential elements of the kite contributing to lateral stability. The greater the extend of the vertical sides the greater the stability in the lateral direction, and the less tendency has the kite to roll or move from side to side , or turn over in the air. The following is a drawing of a typical form of Hargrave kite

AGB

885

1902. Dec. 11. Thursday. At Beinn Bhreagh.

In t he foregoing drawing of a typical Hargrave Kite I have shown only necessary details, with only sufficient frame-work to hold the cells apart. It is obvious that such a kite is a very flimsy construction. T he kite requires additions to the frame-work of various sorts to give it suff. strength to hold these surfaces in their proper relative positions, and to prevent distortion or bending or twisting of kite-frame and surfaces under the action of the wind.

Unfortunately the additions of various sorts required to give rigidity to the frameWork, all detract from the efficiency of the kite as a kite. First by rendering the kite heavier so that the ratio ra tio of weight to surface is increased, and secondly by increasing its head resistance by interior bracing. The interior bracing necessary to preserve the cells from distortion come in the way of the wind, thus adding to the tte drift of the kite without contributing to the lift.

A rectangular cell is structurally weak, as can readily be demonstrated, by the little force required to distort the cell A into the form shown at B below.

IN order to remedy this weakness, internal bracing is required of the character shown below.

This internal bracing even if made of the finest wire so as to be insignificant in weight, all comes in tte way of the wind, increasing 886 enormously the ? h resistance, without any counterbalancing advantage

In looking back over the line of exp. at Beinn Bhreagh, I recognize that the adoption of a triangular cell was a step in advance — constituting indeed one of the mile-stones of progress — one of the points that stand out clearly against the hazy back-ground of a mass of details.

A triangular frame is by its very structure perfectly braced in the direction of its own plane so that internal bracing of any charecter is unnecessary to prevent distortion of a kind analogous to that shown above at B p. 885 for the Hargrave rectangular cell.

While the lifting power of such a cell a triangular cell is probably less than that of the ordinary Hargrave cell, the enormous gain in structural strength, together withthereduction of head— resistance and weig?? due to the omission of internal bracing counter-balance any possible deficiency in th e is respect.

While theoretically the triangular cell practically is inferior in lifting power to Hargrave's four sided rectangular cell , practically there is no sub. diff.. s S o far as I can judge from obs. kites const. on the same general model as the Hargrave but with triangular cells instead of quadrilateral quadrangular seem to fly as well as the ordinary Hargrave from and at as high an angle. Such kites are therefore superior : f F or they fly substantially as well, while at the same time being they are stronger in construction, and offer less head-resistance.

887

While the triangular form of cell shown above is entirely original with myself, it is such a simple and obvious departure from the ordinary Hargrave form, that it seems to me very probable that other experimenters familiar with the rickety character of the rectangular quadrilateral form may also have struck upon the triangular idea . It is almost inconceivable to me that Hargrave himself shd not have tried this form although I have not seen it fig. any where in pub. prints, before my own adoption of it some years ago. Indeed T I have not yet see any pub. description of such a Cell of it at all showing that whatever exp. may have been made by others with triangular cells the importance of the triangular form of structure was not fully appreciated by them. Otherwise they wd have adopted it in practice, and described it in their publications.

While at Minneapolis this summer T I saw a large kite in the air, wh. appeared to be of the triangular form. T I cd not see the details of constr. ssfficiently to be sure of this but it struck me as resembling in a remarkable degree one of my old kites. Mr Gilbert Grosvenor (or perhaps some one else) informed me this summer that he had seen triangular kites either flying in the air or offered for sale quite recently in the U. S., so that it is possible that others may have devel. this form, either independently of me, or through some knowledge of my exp. wh. may have leaked out through personal friends.

However this may be I claim this form as original with myself, and believe that I was the first to appreciate the importance of the tri triangular cell, and adopt it in practice — 888 I cannot tell without reference to note-books in Washington, exactly when I first adopted the triangular constr.. It was a long time ago, certainly not less than two or three years ago.

While these kites were structurally strong in a transverse direction they were structurally weak in the longitudina cy l direction, requiring diagonal bracing, to prevent bending or twisting

The necessary bracing however, not being in the way of the wind, did not materially affect the head— resistance, and was only disadvantageous by adding dead load, thus increasing the ratio of weight to surface.

Passing lightly over multitudinous series details of exp. — (excepting to say au passant - en passant - that the rectangular triangular cells proved to be admirably adapted for building up into a compound cellular structure in wh. the surfaces of adjourning adjoining cells did not interfere with one another) 889 I come to another conspicuous point of advance — another mile-stone of progress — the adoption of the triangular construction in every direction — longitudinally as well as transversely; and the clear realisation of the fundamental importance of the Skeleton of a Tetrhedron tetrahedron — especially the regular tetrahedron — as an element of the structure or frame-work of a kite on flying machine.

A Tetrahedron is a form of solid bounded by four triangular surfaces. T I n the regular tetrahedron the boundaries consist of four equal quadrillateral equilateral triangles.

The regular tetrahedron has four equal triangular faces, and six equal edges. In the skeleton form the edges alone are represented so that the skeleton of the regular tetrahedron is formed by the junction of six equal lines (or rods) so as to form four triangles.

One of the common puzzles for the amusement of children — and adults for that matter — is the following; — Take six matches and with them form four complete triangles.

The difficulty lies in the unconscious assumption of the experiment that these four triangles shd be all on in the same plane, so that he tries to form them by laying the matches down on the table in front of him, and trying to form arranging them in various ways.— which is of course 890 impissible. The moment he realizes that the triangles need not be in the same plane, the solution of the problem becomes easy;

Place three matches on the table so as to form a triangle, and stand the other three up over this like the three legs of a tripod stand

The matches then form the skeleton of a regular tetrahedron.

A frame-work formed upon this model of six equal rods fastened together at the ends constitutes a structure possessing the qualities of Strength and Lightness to an extraordinary degree.. It is not simply braced in two directions in space like a triangle: it It is a the skeleton not of a surface simply — but of a solid having extension in three dimensional space, and is equally well braced in the three directions of space.

If - I may coin a word it possesses three —dimensional strength— — not simply two dimensional strength like a triangle — or one dimensional strength like a rod. It is a the skeleton of a so l lid, not of a surface of a line.

It is astonishing how solid such a frame-work appears even when composed of very f l ight and fragile material; and compound structures formed by fastening these frames together at the corners, so as to form the skeleton of a regular tetrahedron on a larger scale possess es ? equal if not greater solidity.

891

The equadrillateral tetrahed

The equi-lateral tetra-triangular frame ? h as an element of kite structure seems to me to be the most important point yet developed. Just as you can build houses of all kinds out of bricks, so you can build kite structures of almost any form out of these tetrahedr on l cells, and the whole structure will possess the same qualities of solidity and lightness possessed by the individual cells.

Of course the use of such a cell is not limited to the construction of the frame-work of ki l t es or flying-machines, but is applicable to any kind of structure whatever in which it is desirable to combine strength and lightness. T I have already built a house, a frame-work for a wind-break, three or four boats, as well as several forms of kites out of these elements, photos of wh. may be found in the volume of illustrations forming the appendix to this fourth volume of my dictated Notes.

As T I propose to leave tomorrow evening for Montreal with my Father and Mrs Melville Bell, and we expect to have a meeting of the Young Ladies' Club of Baddeck tonight here — I fear I may not be able to complete this dictation so as to cover the third point mentioned on p. 881 — the solution of the problem of Steady Flight.

The condition of the weather is such that it may be possible that the young ladies of Baddeck may be unable to come here this evening in wh case I hope to continue this dictation tonight. I cannot do so tomorrow as it is my last day at the Lab. Mr Zable left Wednesday Dec. 10 for Halifax and Montrealto prepare the way for us and severe and hotel accommodations.

892

The young ladies did not come after all so we have time for a few words

concerning the problem of Steady Flight.

Practically there is little difficulty in making a kite that will fly steadily, by following broardly on the Hargrave lines by having front and rear cells with a broad space bet. and sides either vertical or having a vertical component (oblique sides for example, wh. are the equivalent of horizontal and vertical surfaces of certain extent the horizontal element of an oblique surface tending to support the kite in the air, the vertical element tending to prevent the kite from going over to one side)

The oblique surface A for example may be considered the equivalent of the horizontal surface B and the vertical surface C, but the amount of material required to form the surface A is less than that required for B and C.. The frame-work also necessary to support the surface A is less than the frame-work required to support the two surfaces B and C, from wh. it follows that the oblique surface A while equally efficient as with the two surfaces B and C — weigh r s less thus reducing the ratio of weight to supporting surface. In a triangular cell for example flying with one corner down, the ? V shaped surfaces D and E are equivalent in function to the four surfaces F G H I, but weigh less.

893

While then there is little difficulty in making a steady flying kite on lines already known, it is more difficult if the frame-worg is suff. rigid to retain its form unchanged amid varying conditions of windit is a little more difficult to state the theory of action.

The hypethe sis upon wh. I am working seems to demand careful consideration, because apparently justified by kite models of different form s o Theoritical considerations The theoretical conditions of stability of a body supported over a horizontal surface like the groundare well known: t T he centre of gravity must be (?? rtically) within the base of support. A walking — stick set vertically upon the groundis in a condition of unstable equilibrium: a A man standing with his legs far a part is stably supportedin a lateral direction so long as his centre of gravit u y falls an within the imaginary line adjounying joining his two feet , (linear stability) but his equiebrium is unstable in the fore and aft direction, that i t s at in a direction at right anles with to the line adjourning joining his two feet.) This is what 1 term “ one dimensional stability ” or “ linear stability :” A weight supported on its a tripod stand is in a condition of stable equiibrium both fore and aft, and from side to side, so long as the centre of gravit u y falls very clearly within the imaginarytriangular service surface, bounded by the three imaginary lin is es connecting the three points of support, This is what 1 term “ two dimensional stability ” or “ surface stability ” .

in free air dimensional body supported

But this is not suff. for a body sspported in free air. Here we need “ three dimensional stability ” , or “ solid stability ” . In this case the base of support must not be sim c ly a surface figure or triangle , but the 894 figure of a solid , having extension in the three divisions of space, and the centre of gravity must be within the imaginary bounding surfaces of the imaginary solid form. We shall then have what I term “ three dimensional stability ” . To attain this ideal condition we must have at least four points of support, not all in the same plane. If we connect these points by an imaginary lines they form the outline of a Skeleton Tetrahedron. The Skeleton consists of the form of a solid having extension in thre directions in space — bounded by four triangular surfaces enclosed by six straight lines. So long as the centre of gravity falls within the imaginary figure formed by connecting the four centres of aerial support the body will be stably supported in the air.

Take for example the regular tetrahedron. Four centres of support equidistant from one another three in one plane and the fourth outside:

Perfect stability shd result if the centre of gravity occupies the geometrical centre of the imaginary tetrahedron, and a condition of stable equilibrium would exis ts t if If the centre of gravity is within the tetrahedral form, that is the body will not fall to the ground. I have no time at this late hour to enter into the details of this conception, and must be satisfied for the present in having the 895 general thought expressed.

I shall simply add a few points

The grt point to be aimed at is to have at least four centres of support well seperated from one another, one of wh. is not in the same plane with the others. The grter the seperation the better, and it i n s not nec. that the re se shd be any surfaces betou between. The three legs of a tripod stand are as efficient as a rigid triangular surface equivalent to the imaginar h y base of support.

In a soaring bird I fancy I see a case of “ surface stability ” — the two outstretched wings and the tail giving us three well seperated points of support subst. in the same plane, but this gives the bird stability only in two directions in space while he is unstable in the third direction, so that it requires skill i o n the bird's part to avoid being overturned upset in a squall. n S o long as the wings and tail are subst. horizontal so that taey aee all in the same plane he is manifestly in an unstable condition and he resists a turning movement by elevating or depressing one or more of his surfaces so as to gain a point of resistance outside of that plane. w W hen he raises his wings for example so as to form oblique surfaces like C D and E pp 892, he is subst. elevat e ing two vertical surfaces like F and I p 892 wh. offer resist. to a turning movement.

In the Hargrave kite we have two cells well seperated fore and aft each cell having consid. extension in a lateral direction. We thus have at least three centres of supporting surface, (abc) two of wh. are well seperated in the longitudinal direction, (a from bc) but not so well seperated in the lateral direction bc . The lateral stability wd be improved by having 896 at least two side cells as well seperated from one another laterally as the fore and aft cells are seperated longitudinally . The Hargrave kite has two super-posed horizontal aero-planes besides vertical sides so that it possesses three dimensional stability, but it wd be still further improved by having at least one cell above as well seperated from the plane of the other cells as the fore and aft cells of the ordinary kite are separated from one another.

A compound tetrahedral frame-work is admirably adapted for the support of surfaces arranged subst. in this manner

The perspective drawing is incorrect, but serves to give an idea of the structure. A B are lateral cells on a diff. plane from the lower longitudinal cells C B. and the kite so constructed flies well and steadily. It consists subst. of four cells; and if we substitute for them four points located in their geometric centres, and then connect those points by ?? - imaginary lines, the line connecting the centres of A and B will be horizontal, and at right angles to the horizontal line connecting the centres of the lower cells B C and C D and in a diff. plan plane and the oblique lines required to connect the ends together complete the figure of a regular tetrahedron The centre of gravity of the kite is in the geometrical centre of this imaginary 897 tetrahedron

We have in the Lab. all connected together four kites of the above construction in a similar manner to that shown in the connection of the individual cells A B C D of on the preceeding page, so as to form a compound tetrahedral kite, formed of four tetrahedral kites, like that ill. on p. 896..

By universal consent of the workmen employed in the Lab, this is acknowledged to be the best and steadiest kite we have yet produced. The following is a drawing of it. I will have it photographed tomorrow and developed in Washington, as our photographer George McCurdy is no longer here. It is note-wothy note-worthy that there are no horizontal aero-plane s o i n this kite, (excepting imaginary ones) . All are oblique, like the upraised wings of birds and are in effect both horizontal and vertical surfaces when resolved into these elements. I in a similar manner to that shown for the surfaces D E p. 892

End of Volume IV of my dictated Notes. There is an to this volume containing photographs of apparatus constructed at Beinn Bhreagh Laboratory during the summer and autumn of 1902.

The typewritten have been taken down life by my wife. AGB AGB